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ABSTRACT

This student guide and accompanying teacher's guide are a product of the Foundational Approaches in Science Teaching (FAST) curriculum development project at the University of Hawaii. In the teaching guide, the introduction gives a description of the underlying theory and practice in FAST and includes the FAST instructional model, descriptions of FAST courses, a conceptual framework of the local environment, a schedule and sequence of the units, a description of FAST instructional materials, and a safety advisory. Both the student and teacher guides are made up of eight investigations separated into three sections. In Section A, "Water in My Community," students investigate the water cycle, uses of water, the distribution of water, and local resources related to water resource management. In Section B, "Monitoring Water Quality," students investigate testing water quality, purifying water, and managing water resources. In Section C, "Making Decisions," students simulate the planning of a community in which the dominant feature of the area is a marsh. In the teacher's guide, each investigation includes the following sections: review, introduction of new work, student activities, summary, challenge, rationale, overview, materials, and notes. In the student guide, each investigation may contain the following sections: background information, activity, materials, procedure, summary, and challenge. Concluding the teacher's guide are visual aid and student record book masters. (MDH)

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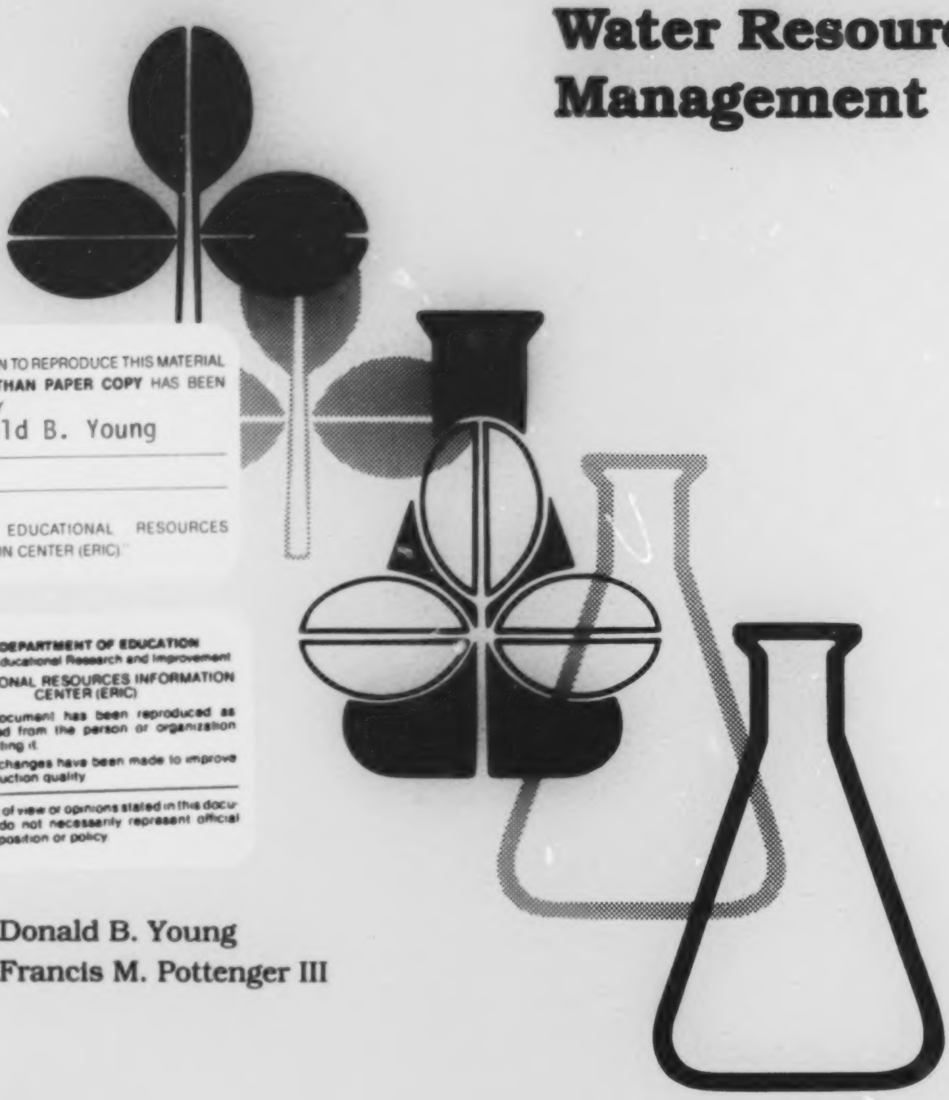
Water Resource Management



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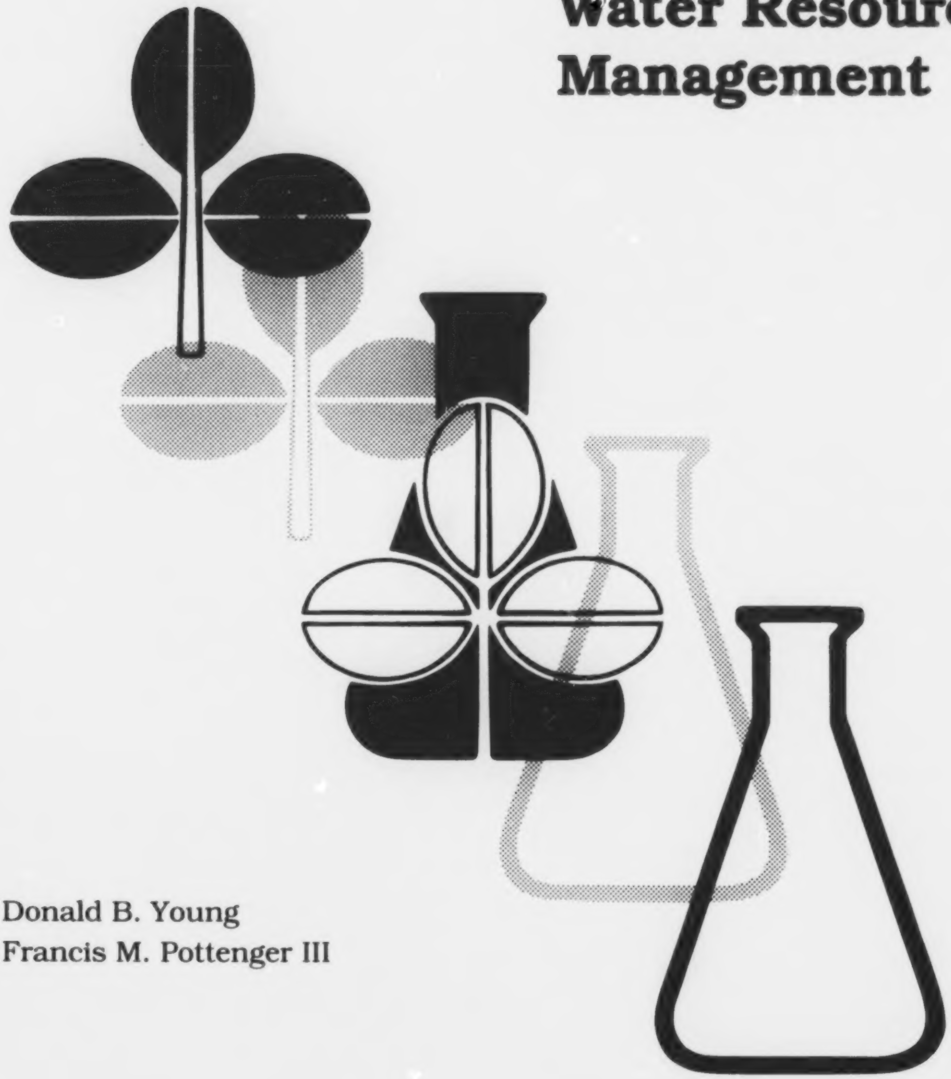

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CONTENTS

PREFACE v

INTRODUCTION FOR STUDENTS vii

SECTION A. WATER IN MY COMMUNITY

1. The Water Cycle 1
2. Uses of Water 5
3. Distribution of Water 10
4. Local Issues 21

SECTION B. MONITORING WATER QUALITY

5. Testing Water Quality 27
6. Purifying Water 56
7. Managing Water Resources 63

SECTION C. MAKING DECISIONS

8. Planning for the Future: A Simulation 69

PREFACE

The *Foundational Approaches in Science Teaching (FAST)* program is one of several curriculum development projects of the Curriculum Research & Development Group (CRDG) of the University of Hawaii. CRDG is a branch of the College of Education. The CRDG staff of about a hundred members conducts curriculum research and design, develops and evaluates educational materials, disseminates them, and offers training and follow-up services. CRDG programs serve children and youth at preschool, elementary-school, middle-school, and high-school levels. Its programs are tested and used in the University Laboratory School, in the schools of Hawaii, in selected schools in the Pacific Basin, and in the United States generally.

Members of the *FAST* staff have developed a series of interdisciplinary science courses that emphasize the foundational concepts and methods of the physical, biological, and earth sciences. By directly involving students in investigating events in their everyday environment and carrying out experiments to answer some of their questions, *FAST* courses give students a sense of how the modern scientific community operates. This process of inquiry and subsequent research is used throughout each course.

Students in *FAST* courses study several disciplines, including physics, chemistry, earth science, and biology. In addition, *FAST* includes study of the interrelationships among science, technology, and society in a component called Relational Study. Thus, through an inquiry approach, these courses give students an understanding of both the concepts of science and their applications to the everyday environment.

Titles of the courses developed thus far are *The Local Environment, The Flow of Matter and Energy through the Biosphere, and Change over Time.*

INTRODUCTION FOR STUDENTS

The *FAST* Water Resource Management unit is part of the Relational Study strand of the *FAST* program. It is a culminating unit of *The Local Environment*. In this unit students apply the knowledge and skills they have developed during the year to the study of a local environmental issue—the management and control of water resources. Through these investigations they see that science is but one contributor in decisions about the use of environmental resources. Science, technology, and society all interact in the process.

Because this unit follows physical science investigations of buoyancy, density, change of state, and fluid mechanics and ecology investigations of plants, animals, soils, and the water cycle, you will find occasional references to those investigations in this unit.

STUDY AIDS

This booklet is organized to help you understand explanations, follow directions, and review major ideas.

1. New science words are printed in *italics*.
2. Points of special importance in experiments are printed in **boldface.**
3. Cautions and safety notes are also printed in **boldface.**
4. In the summaries of investigations, the key questions are marked with a key (🔑).
5. At the end of each section is a list of words you should learn because they are part of the scientist's vocabulary.

INVESTIGATIONS

Each investigation has six parts:

Background introduces the investigation and reviews earlier related investigations.
Problem or **Activity** tells what you are to investigate.
Materials lists the things you will need to use in an investigation.
Procedure gives you instructions for doing an investigation.

Summary lists a set of steps or questions to help you summarize and interpret your findings.

Challenge provides a set of additional investigations or questions that can expand your understanding of work you've already done.

LABORATORY SAFETY

Follow these safety rules in all laboratory classes:

1. Always wear a lab apron to protect your clothing and your skin.
2. Always wear goggles when you work with chemicals, hot liquids, or other things that could harm you.
3. Always stand up to avoid spilling chemicals in your lap while you do investigations.
4. Always wear closed shoes to protect your feet from spills.
5. Wash at once with plenty of water to dilute and remove chemicals if you spill them on your clothing or skin.
6. Never taste any chemical unless your teacher tells you to.
7. Tie or pin your hair back to keep it away from flames and chemicals.
8. Know where the fire blanket and fire extinguisher are and how to use them in emergencies.

Section A. Water in My Community

1. THE WATER CYCLE

Background

In the Ecology strand of this course we investigated the interactions of plants and animals in the class study area, the movement of water through soil and air, and water coming out of plants in transpiration. Wherever we look in the environment, we seem to find water.

In the Physical Science strand we did experiments on the buoyancy of water, on its changes of state in boiling, freezing, melting, and condensing, and on its movement in the presence of pressure and vacuums. We found that water can change state as it moves through the environment.

In this unit we will use our knowledge of the properties of matter and interactions in the environment to study a community problem—water resource management. For such a study we must apply and extend our knowledge of science, and we must identify and discuss the social, political, economic, and technological aspects of this problem.

We will look at water resource management from the viewpoints of scientists, technologists, politicians, economists, and—most important—citizens of the community.

First we will review what we already know about water relationships. Then we will investigate some questions: How is water used in the community? How is it distributed through the community? What happens to water after we use it? How clean is the water we use? How can water be purified? Who controls the use of our water?

We will begin by describing the *hydrologic cycle*—the flow of water through the environment.

Activity

Trace the flow of water through the environment.

Materials

- Water Game
- materials for projects

Procedure

1. Organize the class into groups of three or four students each.

2. Review Ecology Investigations 8 through 25. Also review Physical Science Investigations 18 through 33.

   In your group discuss the flow of water through the environment. Base the discussion on what you learned in your investigations and experiences.

3. Using the diagram below as a guide, trace the flow of water through the environment. Identify as many pathways as you can. A copy of the diagram is in the Student Record Book.

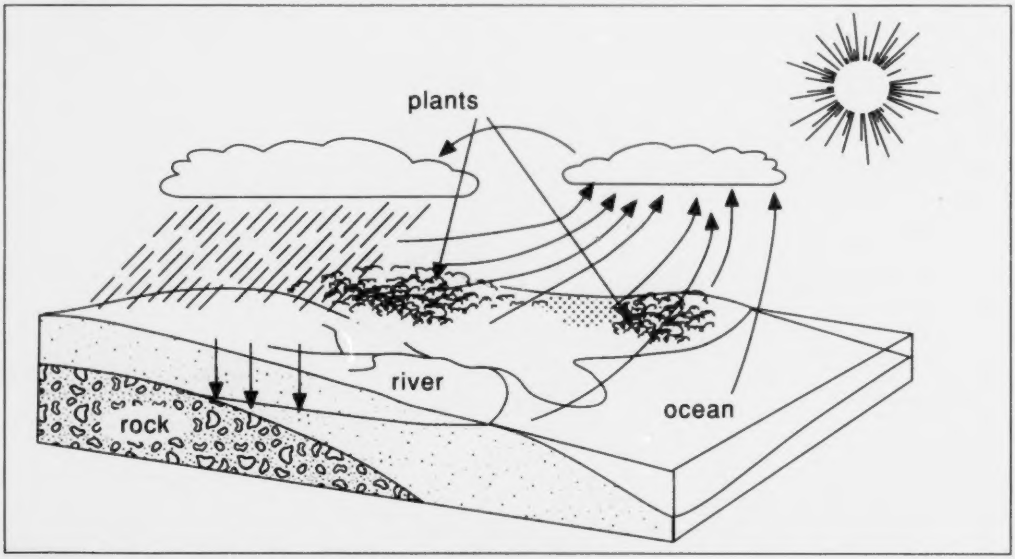


Figure 1–1 Tracing the hydrologic cycle

10

4. Play the Water Game in your group. Your teacher will give you the materials and directions for the game.

5. Choose one of the projects below to illustrate the water cycle. Plan and carry out the project with your group.

   a. Write a story about four raindrops each taking a different path through the environment until they rejoin in a new rainfall. Illustrate your story. Share it with the class.

   b. Create a skit that shows the flow of water through the hydrologic cycle. Perform your skit for the class.

   c. Write a poem about the water cycle. Share it with the class.

   d. Make a collage using pictures from magazines and newspapers to show the water cycle. Post the collage in the classroom.

   e. Set up a closed terrarium to show the hydrologic cycle. Refer to the reference booklet "Animal Care" for information on setting up a terrarium.

   f. Begin a news file of articles or reports about local water issues. Keep the file in the classroom so that others can add to it.

Summary

1. Share your project on the hydrologic cycle with the class.
2. What are the sources of energy that drive the water cycle?

Challenge

1. How could water in the hydrologic cycle become polluted?
2. What other cycles in nature can you identify? Try to name and describe at least two cycles other than the hydrologic cycle.
3. In some places agricultural crops are being grown in the desert with fossil water. What does "fossil water" mean? Try to find information about this practice, including the amounts of water used, its source, and its effect on raising food crops.

2. USES OF WATER

Background

Hydrology is the study of the movement and distribution of water on Earth. In nature, water circulates through the *hydrologic cycle*. Heat from the sun makes surface water evaporate and change to water vapor. When water vapor in the atmosphere cools, it condenses, forming clouds. When sufficient liquid or solid water collects in clouds, it falls in the form of rain, snow, sleet, or hail, collectively known as *precipitation*. When water reaches the ground, it may seep or flow into lakes and oceans. Eventually, water works its way to the surface, evaporates, and begins the cycle anew.

Water is a vital resource. We use it for drinking, cooking, cleaning, grooming, manufacturing, growing food, and disposing of wastes. Water is used in homes and hotels, on farms and golf courses, in factories and public buildings—in fact, wherever humans live and work. With so many people needing water, is there enough to go around?

Problem

How much water do you use?

Materials

- chart paper
- graph paper
- colored pens

Procedure

1. Divide the class into groups of three or four.

2. In your group create a concept map on water uses.

   a. Write WATER USES in the center of a large sheet of paper and build a concept map of your group's ideas.

      WATER USES

   b. Think about water. What do you know about it? How do we use it? Where does it come from?

   c. Write words on the map to name the uses, sources, properties, and anything else that affects the use of water. Draw lines to show connections. Label the lines.

3. Prepare a class list of water uses.

   a. Organize the list into groups of similar kinds of uses.

   b. Identify the uses of water that affect you personally.

4. Estimate how much water your family uses in a day.

   a. Use Table 2–1 to estimate the amounts of water you use in family activities. Determine whether your family members are normal or conservative users of water.

Table 2–1 My family's daily water usage

Type of Use	Average Amount of Water Used (gallons)		Number of Uses per Day	Estimated Total Water Used per Day (gallons)
	Normal	Conservative		
Showering	25	4		
Bathing	36	12		
Brushing teeth	10	0.5		
Shaving	20	1		
Dishwashing by hand	30	5		
Dishwashing automatic	16	7		
Washing hands	2	1		
Flushing toilet	5	4.5		
Washing clothes	60	27		
Watering lawn by hand	10/min.			
Watering lawn automatic	500			
Washing car	150	50		
Cleaning sidewalks	10			
Cooking				
Drinking				

Number of people in my family ____

    b. Add other uses from your concept map.

    c. Observe and record the amount of water you drink in one day as well as the amount of water required by your additional uses in 4.b.

    d. Calculate the total amount of water your family uses in a day.

    e. Calculate the average amount of water each person in your family uses in a day.

    f. As an alternative to completing Table 2–1, or as a comparison, get a recent water bill from your family. Locate the total amount of water used. Calculate the average amount of water used per person each day in your family.

5. Compare your daily consumption of water with others in the class.

    a. Prepare a class graph showing the amount of water used by each person in the class per day. Post the graph in the classroom.

    b. Calculate how much water is used by the whole class in a day, a week, a month, and a year.

    c. Calculate the average amount of water used per person in your class.

    d. Estimate the amount of water used by students and staff in your school in a day, a week, a month, and a year.

Summary

1. How much water have you used in your lifetime? How did you make your estimate?
2. Check with school officials or the community water department to find out how much water your school uses in a month.
3. Where else is water used in your community other than in homes and schools? Which uses of water in your community are essential?
4. How can the amount of water available to your community be increased?
5. How can the amount of water used be reduced?
6. Refer to your concept map on water uses. Make a class collage on water uses. Post it in the classroom near your graph of water use.

Challenge

1. What are some uses of water not common 50 years ago that are common today? How has the amount of water used per person changed in the last 50 years?
2. Plan and carry out a water conservation project in your home, school, or community. Report on the results of your project.

3. DISTRIBUTION OF WATER

Background

We all use water in many ways, but we need to have fresh, clean water for drinking and cooking. The two main sources of fresh water are groundwater and surface water.

Groundwater seeps through soil or through cracks and cavities in rocks. *Surface water* flows over land, then collects in lakes, rivers, streams, and reservoirs.

Groundwater

Groundwater lies below the surface of the earth. It is the source of water for wells and springs. About 35% of the public water supply in the United

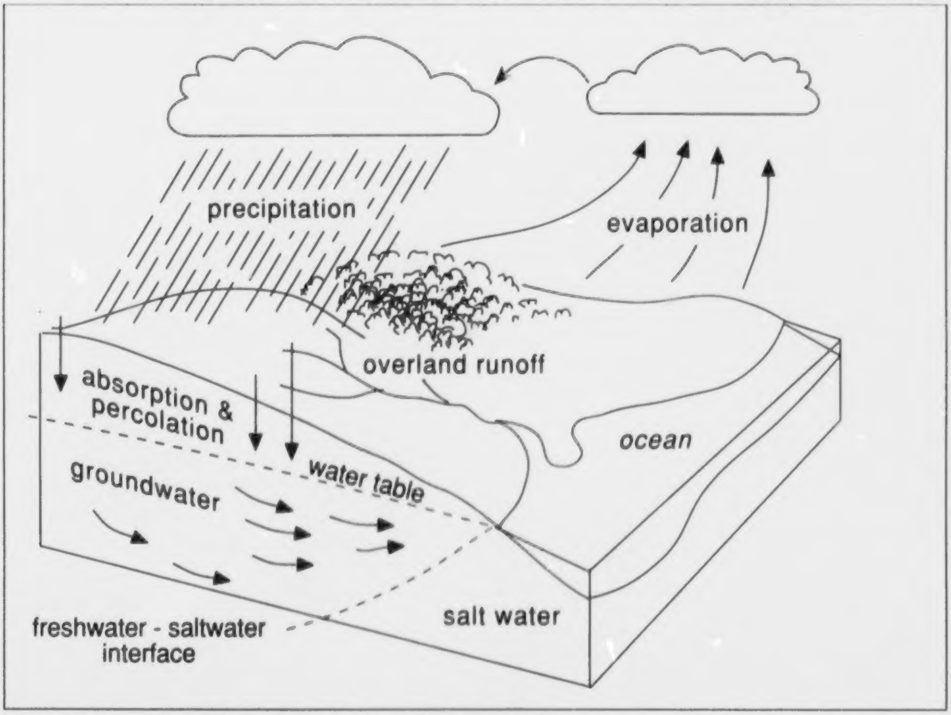

precipitation
evaporation
overland runoff
absorption & percolation
ocean
water table
groundwater
salt water
freshwater - saltwater interface

Figure 3–1 Groundwater in the hydrologic cycle

States comes from groundwater. Most rural areas and some cities depend heavily on groundwater to meet their needs.

Most groundwater comes from rain that filters through the soil by *percolation*. (Recall your studies of the interactions of water and soil in Ecology Investigations 9 and 10 on absorption, percolation, and capillarity.) Water settles into pores and cracks in underground rocks and into spaces in sand and gravel. A layer or bed of porous material that holds useful amounts of groundwater is called an *aquifer*. Wells drilled down to an aquifer draw groundwater to the surface.

The top level of groundwater, called the *water table*, drops when more water is withdrawn than is replaced. In places that have little rainfall or large human populations, the groundwater supply is sometimes used up faster than it is replaced. This lowering of the water table causes problems in coastal areas when salt water from the ocean enters the aquifer.

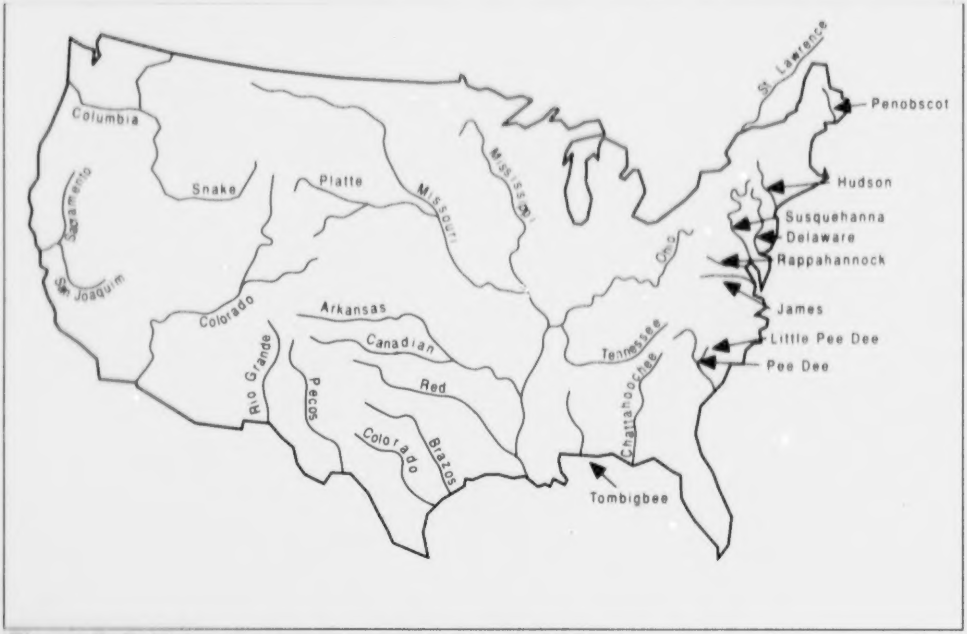
Water is constantly on the move in the hydrologic cycle. As you can imagine, the rates of movement differ. See Table 3–2.

Table 3–2 Rates of movement and distribution of water

Location	Rate of Movement per Day	Percentage of Water Supply
Atmosphere	100s of kilometers	.001
Land surface	10s of kilometers	.019
Below land surface	meters	4.120
Ice caps and glaciers	centimeters	1.650
Oceans	—	93.960

Surface Water

River, stream, brook, rivulet, freshet, arroyo, bayou, creek, slough, rill, runnel—these are some of the dozens of names for flowing water. Hydrologists usually refer to smaller bodies of flowing water as *streams* and larger bodies of flowing water as *rivers*. When streams join with other streams, they form a branching network called a *river system*. The river system is fed by rain and snow and by groundwater seeping from aquifers.



St. Lawrence
Penobscot
Columbia
Snake
Platte
Missouri
Mississippi
Hudson
Susquehanna
Delaware
Rappahannock
Sacramento
Ohio
San Joaquin
Colorado
Arkansas
James
Canadian
Tennessee
Little Pee Dee
Pee Dee
Rio Grande
Red
Pecos
Chattahoochee
Colorado
Brazos
Tombigbee

Figure 3–3 Major river systems of the United States

Most rivers don't start out big. Instead, they grow as their *headwaters*—the streams that flow into the river—begin to join together. The area of land that draws rainfall and snowmelt from headwaters into a river system is called a *watershed*.

Rivers differ not only in the rate of water flow but also in the composition of their bottoms and in the forms of life they have in them. Near their headwaters rivers may flow fast, grinding out canyons and creating rapids and waterfalls. Currents are swift in these clear, cold, highly aerated waters, yet the volume of water is low. Trees, shrubs, and grasses shade the water, bind streambank soil with their roots, and provide food for stream life.

Plants and animals living in these rivers are adapted to the fast-moving water and generally rocky bottom. Many animals have claws or suction cups on their feet for hanging on; some have flattened bodies for squeezing under rocks; others have strong appendages for bracing themselves against the forceful flow of water.

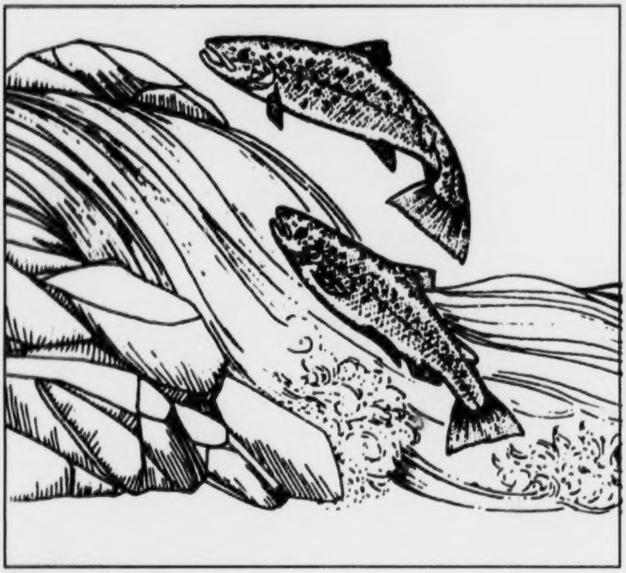


Figure 3–4 River life

As more streams flow into a river, it gets wider and wider. When the water reaches flatter land, its rate slows. As sediment is carried downstream and accumulates on the bottom, the channel widens. As the river slows, flat stretches of land called *flood plains* form on either side. During storms, rivers may overflow onto the flood plain. Then as the water recedes, it leaves deposits of rich sediment behind, making the flood plains fertile and productive.

These larger, slower rivers support diverse communities of algae, catfish, turtles, dragonflies, and other plants and animals that thrive in oxygen-poor waters. These rivers can also support a diverse shore community of kingfishers, herons, otters, raccoons, and other creatures that depend on the river for food and water.

Wide, slow-moving rivers carry huge volumes of water. Along their shores *marshes* and *swamps* form. At an "old" river's *mouth*, most often a lake or ocean, the flow of water slows even more and dumps most of the leftover sediment. This sediment creates new land, called a *delta.* Where a river meets the ocean, salty water mixes with fresh water, creating an *estuary*—a rich habitat for life and a productive nursery for young shrimp, crabs, ocean fish, and other animals and plants.

Wetlands

Wetlands—swamps, marshes, bogs, and prairie potholes—are land areas saturated with or covered by water at least part of the year. Wetlands can form where water collects in depressions in land or where soil, plant matter, and animal matter collect in ponds or along rivers. As sediments settle out, the water becomes shallow. Plants adapted to such conditions gradually establish themselves here.

Many people believe that wetlands are the most productive natural systems on Earth because they support a rich variety of plant and animal life. Wetlands also protect against flood damage by absorbing large volumes of water, thereby protecting lives and property downstream.

Swamps are wetlands where trees grow. Swamps support hundreds of species of birds, mammals, reptiles, amphibians, fish, and insects. Some swamps contain *bayous,* which are slow-moving streams. Bayous can be so narrow that mosses hanging from trees on opposite sides meet in the air above the water.

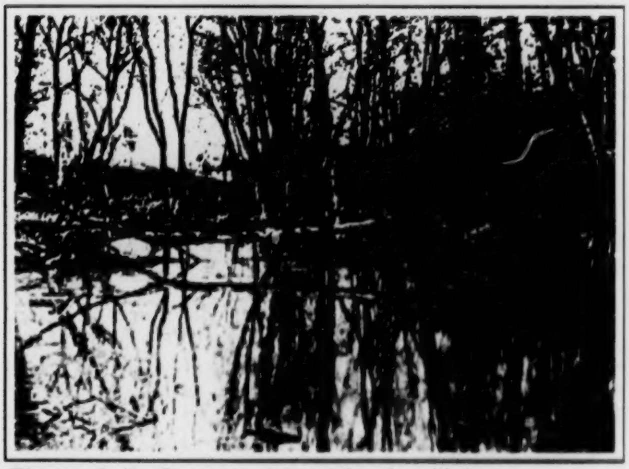


Figure 3–5 Swamps are wetlands with trees

Salt marshes are the coastal nurseries of the ocean. Many nearshore and offshore organisms begin life here. The ocean food web begins in marshes where outgoing and incoming tides create unique conditions for life. As tides go out, they carry leaves and dead matter from the marsh to the ocean, where it becomes food for many ocean animals. When tides come in, they carry ocean minerals and salts that become nutrients for plants growing in the marsh.

This exchange of food and nutrients constitutes one of the most productive ecosystems in the world. Many marine animals spend part or all of their lives in marshes. Seven of the ten most economically valuable fish and shellfish—shrimp, salmon, oysters, menhaden, crabs, flounder, and clams—need marshes for breeding. Of the ten, only tuna, lobster, and haddock neither breed nor live part of their lives in marshes. Two thirds of the fish harvested from the Atlantic and Gulf coasts and a third of those taken from the Pacific depend on these wetlands for breeding.

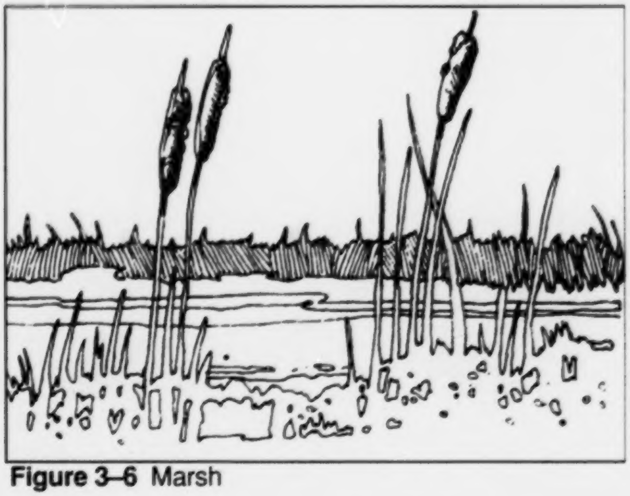


Figure 3–6 Marsh

Bogs usually form in glacial and mountain lakes that have no outlet. The water is cold and still. Because it is low in oxygen and high in acid, few plants and animals live there. But there are lots of insects and insect-eating plants such as bladderworts, pitcher plants, and sundew. These plants usually grow in a thick layer of peat moss called sphagnum. The moss looks sturdy enough, but because it sometimes shakes when someone walks on it, it is often called a "quaking bog."

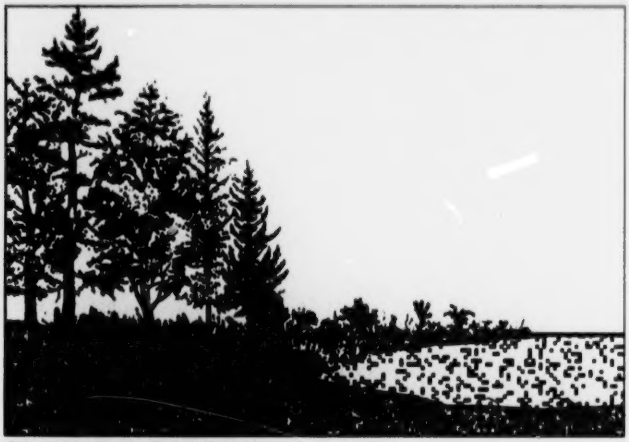


Figure 3–7 Quaking bog

Prairie potholes are miniature marshes found in Iowa, Minnesota, Montana, Nebraska, and the Dakotas. They are the most important breeding grounds for waterfowl in the United States. These small marshes formed where glaciers left shallow depressions in the earth. Some prairie potholes hold only a few centimeters of water for just a few weeks in the spring. Others hold water up to 6 meters deep during the rainy season. Waterfowl use prairie potholes for breeding; they use wetlands of all kinds for feeding and resting.

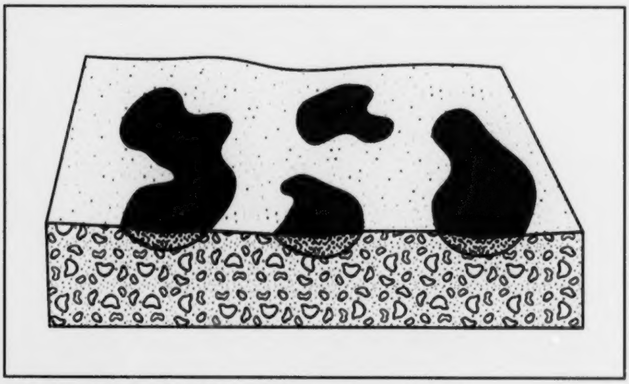


Figure 3–8 Prairie potholes (aerial view)

Problem

Where does our water come from?

Materials

- audiotape player
- tape of Bedrich Smetana's *The Moldau*
- topographic map of area
- tracing paper

Procedure

1. Before you begin this investigation, listen to the sounds of moving water. Get a tape of the musical composition *The Moldau* by Bedrich Smetana. Listen to the tape in class.

   Smetana, a composer who lived from 1824 to 1884, was proud of his home country in what is now Czechoslovakia. He wrote music to represent different parts of it. Of his compositions, one of the most famous is *The Moldau*, which he wrote to depict the longest river in his country.

   a. Listen to the musical sounds of the movements of the river. Try to picture the images the composer is trying to interpret in the music. Your teacher will give you descriptions of parts of the Moldau River.

   b. Listen to other compositions about water, such as Respighi's *Fountains of Rome* or Handel's *Water Music*.

2. Divide the class into groups of three or four. In your group make a map of your watershed.

   a. Get a topographic or highway map of your region that shows the streams or rivers flowing through your community.

   b. Using tracing paper, trace all the rivers and streams shown on the map.

   c. Outline the drainage area that forms the watershed for your community.

   d. Compare your group's watershed map with maps made by other groups. Make a large class map of your community's watershed.

3. Using your map, find the main water source for your community. Find out whether your community relies on surface water or groundwater.

4. Find out how water is distributed from its source to where it is used in your community.

   a. The pipes delivering water to your home or school are usually buried. Look for evidence of the water distribution system such as fire hydrants, buildings, sprinklers, and other water distribution points. Imagine how the water distribution system works in your community.

   b. Make a large-scale drawing showing the distribution system from the water source to your school.

5. Find out how water gets to classrooms in your school.

   a. Go outdoors and find the following:

      - water valves
      - water meter
      - water main leading into the school
      - water fountains or sprinkler heads
      - fire hydrants

   b. Inside the school locate the following:

      - drinking fountains
      - water pipes under sinks
      - source of hot water (check the cafeteria or the central heating system)

   c. From the information you gather make a scale drawing of the water distribution system in your school.

   d. Compare your drawings with actual plans or blueprints obtained from the office or the custodian.

Summary

1. Discuss the scenes depicted in the music of water movement.

   a. Can you draw or sketch the images the music created in your mind?

   b. How does the movement of water affect your feelings?

†2. Refer to the class map of your watershed area.

   a. What other communities are affected by your watershed area?

   b. What kinds of industry or agriculture are in your watershed area? How might they affect the quality of your water?

   c. What other communities might be affected by sewage or wastes going into streams in or near your community?

3. How do urban areas affect what happens to rain that falls there?

†4. Who is responsible for maintaining the water distribution system in your community?

   a. Who pays the costs of maintaining the system?

   b. Who makes decisions affecting the water distribution system?

   c. How large a population can the water distribution system serve?

Challenge

1. Invite an engineer from your water department to speak to the class about the water distribution system in your community.

2. Find the meaning of the following:

   - normal peak demand
   - per capita consumption
   - water pressure
   - pumping station
   - gravity distribution

3. Make a scale drawing of the water distribution system in your home.

4. Make a model of the water distribution system of your school or home. Share your model with your class.

4. LOCAL ISSUES

Background

We have investigated the natural water system around our community and the ways we use water. Now we turn to local issues of water resource management, trying to answer such questions as who owns the water, how the supply is regulated, how demands for clean water are changing, and what steps are being taken to keep our water clean.

Problem

1. What are the local issues of water resource management?

2. How are these issues being resolved?

Materials

- newspaper articles
- class scrapbook or newspaper files
- chart paper
- colored pens
- regional atlas
- census data on local population size

Procedure

1. Refer to your local newspaper for information on current local issues in water resource management. Newspaper articles often identify and give thorough information about controversies.

    a. Begin a newspaper file on water resource management issues. Review old newspapers for articles on water resource management in the last year and collect new articles.

b. Analyze each article for the following information:

   - What does the article say about water? Does it describe uses, amounts, costs, or quality?
   - What is the position or opinion of the person who wrote the article?
   - Are several opinions expressed? What are they?
   - Is a conflict mentioned, either directly or indirectly? What is it?

c. Keep the articles in a class scrapbook. Write a summary of each article and put it in the scrapbook with the article.

2. Using an atlas, an encyclopedia, geography books, or other sources, find the amount and distribution of each of the following in your state:

   a. Annual rainfall

   b. Agricultural areas

   c. Population centers

   d. Industrial centers

   e. Major rivers

3. Make a large class map of your region. Using different colors, show the information your class gathered in procedure 2. Post the map in the classroom.

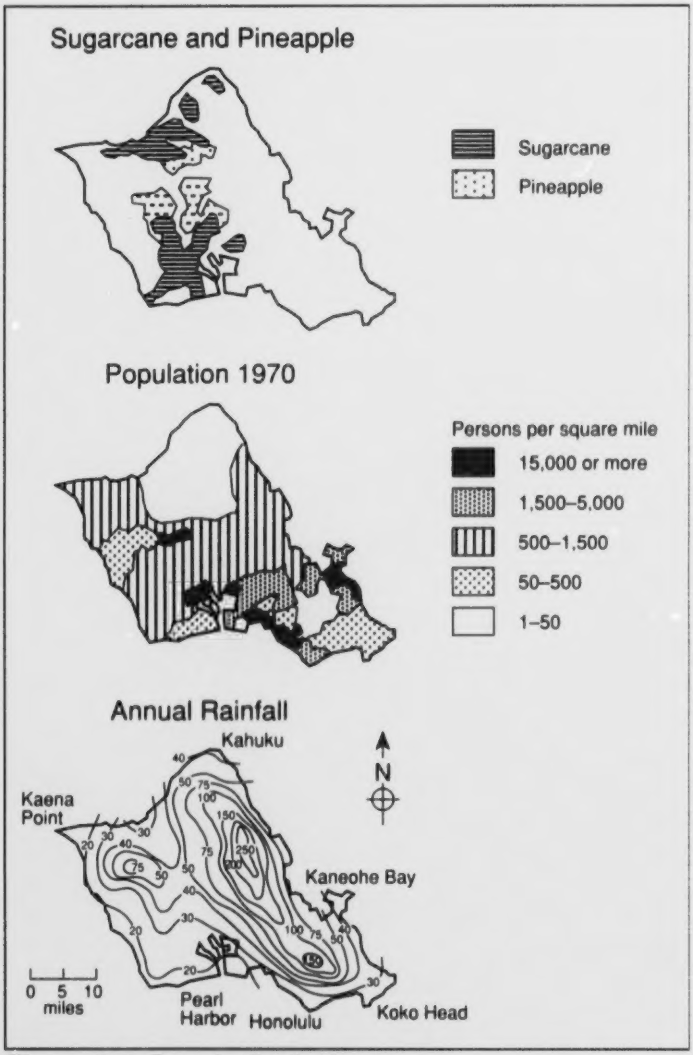

Sugarcane and Pineapple
Sugarcane
Pineapple
Population 1970
Persons per square mile
15,000 or more
1,500–5,000
500–1,500
50–500
1–50
Annual Rainfall
Kahuku
Kaena Point
N
Kaneohe Bay
0 5 10
miles
Pearl Harbor
Honolulu
Koko Head

Figure 4–1 Sample distribution maps

4. Find out how the population of your region is changing. Population size has an effect on the demand for water.

    a. Find out what the population of your community is now.

    b. How has the population size changed in the last 50 years? What is happening to the population size now?

    c. Refer to your data from Investigation 2, Uses of Water, on the average amount of water used per person in your class. Estimate the amount of water needed by your community in one day and in one year.

5. From your newspaper file and other information you have gathered, find out who controls water use in your community.

    Discuss these questions in class:

    - Who owns the water in your community?
    - Are there some community members who do not pay for water?
    - Who regulates the amount and cost of water used in your community?
    - How are members of the regulatory agency selected? Who pays them?
    - Whose interests do members of the regulatory agency represent?

6. Divide the class into two teams. Prepare and carry out a debate on the issue below or another issue chosen by the class. One team should support the statement while the other team challenges it.

ISSUE: Water should be free for all to use as much as they want.

You may want to have some classmates videotape the debate and role-play a television news team covering this community event.

Summary

1. Analyze your map of rainfall, rivers, population centers, industrial areas, and agricultural areas.
    a. Why do you think the population centers are where they are?
    b. What problems or issues related to water use might arise from these distributions?
2. Explain the water resource management issues in your community in one of the following ways:
    - Plan and put on a skit about an issue.
    - Write a research paper on an issue.
    - Write and perform a song, poem, chant, or rap about an issue.
    - Create a poster highlighting an issue.
    - Create and record a TV commercial representing different interests in an issue.
    - Conduct a mock newspaper or TV interview of interest groups' positions on an issue.

Challenge

1. Attend a hearing or a community meeting on a water resource issue. Report your experience to the class.
2. If you were going to build a new community, how would you select a place for it? What points would you consider? What would be the most "logical" place for people to live?
3. Find out what federal laws affect water quality in your community.

4. Prepare summary reports of water issues in your community. Share your reports with students in other classes, schools, states, or countries. How are the issues similar? How are they different?

New Vocabulary for Section A

- aquifer
- bayou
- bog
- delta
- estuary
- flood plain
- groundwater
- headwaters
- hydrologic cycle
- hydrology
- marsh
- percolation
- prairie pothole
- river
- river system
- salt marsh
- stream
- surface water
- swamp
- water table
- watershed

5. TESTING WATER QUALITY

Background

Water is vital. All living things depend on it. Without water, they die.

But when we use water, we contaminate it with substances that make it unhealthy for living things. Used water, called *wastewater* or *sewage*, from homes, businesses, and industries may contain bacteria, suspended solids, phosphates, nitrates, and a host of other chemicals. Such contaminated water may be low in oxygen, making it impossible for some organisms, such as fish, to live in it. But other organisms, such as algae, thrive in such an environment, where they create foul-smelling, polluted water.

Human use isn't the only source of water pollution. A *source* is a starting place, thing, or process. In water studies a source is anything that releases pollutants into the hydrologic cycle. Agriculture is a source of pollution when fertilizers and pesticides enter our water or when soil erosion and runoff add silt to streams, rivers, and lakes, clogging or choking water flow.

Industries also use large quantities of water, but they do not usually need water of high quality. Some industries dump waste that contains solids, chemicals, or radioactive substances. Water used for cooling machinery gets hot; if it is dumped into a stream or lake, it too affects the lives of organisms.

Problem

What evidence of water pollution, if any, can you find in your community?

Procedure

1. Refer to the class map of the watershed of your community or region that you made in Investigation 3, Distribution of Water.

a. Prepare a Water Pollution Source Map of your community. Locate possible sources of pollutants on the watershed map.

There are two kinds of sources of water pollution. A *point source* is a well-defined spot such as a place where a pipe from a factory enters a stream. A *nonpoint source* is a large area such as grazing land, a logging area, a construction site, an abandoned mine, and gardens, lawns, and streets in cities. Pollution from a nonpoint source doesn't enter the water system at a single point.

Sediments are the major component by weight of nonpoint source pollution. Other nonpoint source pollutants include fertilizers and animal wastes from agriculture, septic tank breakouts, and runoff from urban gardens, lawns, and landfills.

b. Invent a color key to mark different kinds of sources on your map. Then color the sources on the class map.

c. Post your color key for sources next to the map, which we will call a Water Pollution Source Map.

d. Add other information to the map as you complete the investigations in this unit.

2. Arrange to go to a nearby water study area—a stream, lake, pond, or wetland—to collect water samples and test them. If possible, you should sample and test water several

times before drawing conclusions. Alternatively, bring water samples to class for testing. If possible, compare water samples from several sites.

3. Divide the class into six teams of three to five. Each team should conduct one or more of the tests shown in Table 5–1. The tests are described on the following pages.

Table 5–1 Team assignments for testing water quality

Team Name	Chief Job	Page
A. Environment	Sketch and describe the water study area; measure depth, velocity, and temperature of water.	32
B. Dissolved substances	Measure acidity and salinity.	36
C. Dissolved gases	Measure carbon dioxide and oxygen content of water.	41
D. Nutrients	Measure nitrate and phosphate content of water.	45
E. Suspended solids	Measure total suspended solids and turbidity.	48
F. Living organisms	Note biological indicators, odor, plankton, bacteria.	51

Summary

1. Summarize all your data in a form similar to Table 5–2. Use a separate form for each site where you tested water. Post the forms next to your Water Pollution Source Map.

2. Each team should prepare a report for the class on its findings.

   a. After the reports are complete, discuss with the class the general quality of the water in the water study area.

   b. Decide what steps to take to maintain or improve the water quality.

   c. Prepare a plan for carrying out the decisions.

13. Share your reports and your plans with classes in your city, state, or even another country.

   a. How are the reports and plans similar?

   b. How do they differ?

Challenge

1. How can a hydrometer be used to measure the salinity of water?

2. Design an experiment to test the effects of acid rain or other pollutants on plants.

   a. Write your plans for your experiment. Include a flow diagram.

   b. Get your teacher's approval and support before you start your project.

   c. Carry out your experiment and report on the results.

Table 5–2 Water quality report form

WATER QUALITY REPORT FORM

Water station location ______________________ Date ______________

Reporter ______________________________ Time ______________

Measurements made

1. Water depth ______________ 2. Rate of flow ________________

3. Water temperature __________ 4. Air temperature ____________

5. pH ____________________ 6. Salinity ___________________

7. Dissolved oxygen __________ 8. Dissolved carbon dioxide ________

9. Nitrates _________________ 10. Phosphates ________________

11. Total suspended solids _______ 12. Turbidity __________________

13. Bacterial count ____________

Visible pollutants

14. In sample _______________ 15. At site ____________________

Other observations

TEAM A. ENVIRONMENT

A dynamic, thriving community depends on the interactions of the physical and biological factors in the environment. The chief job of the Environment Team is to sketch the water study area and describe some of the factors that influence and help us interpret water quality measurements.

Materials

- large sheet of map paper
- several stringed metersticks
- thermometer
- stopwatch
- 2 stakes
- weighted string
- long pole
- hammer
- orange, ball, or similar floating object

Directions

1. On a data table similar to Table 5–4, sketch the water study area. See Ecology Investigation 27, The Initial Survey, for information on making an initial survey map of an area.

    a. Pace distances to prominent objects and plants. Locate these on your sketch.

    b. Estimate the width of the water study area.

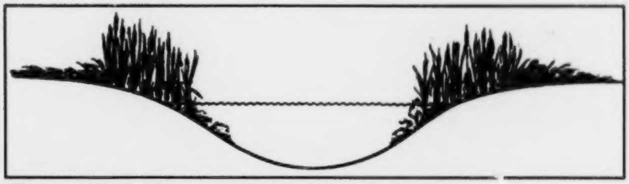


Figure 5–3 Sketch of a water study area

c. On a large sheet of map paper, outline the water study area. Transfer your data to the large map. Show the approximate scale of the map. Indicate which way is north.

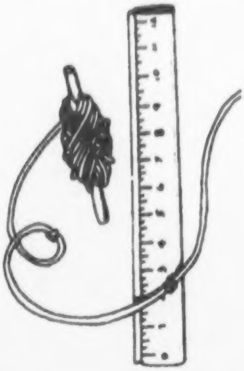
d. Make your map as detailed as possible.

Table 5–4 Data on our water study area

Sketch	Location	Water Depth	Temperature Air Water	Rate of Flow

2. Use a stringed meterstick, a weighted string, and a long pole to measure the depth of water at various places in the water study area. Record your measurements on the map of your water study area.

Trial	Depth
1.	
2.	
3.	



Average depth: _____

Figure 5–5 Measuring the depth of water

3. Measure the temperature of the air. Measure the temperature of the water at several depths. Record these data on your map.

4. Measure the rate of water flow, if any. (The rate of flow helps determine the kinds of food in the water and the feeding strategies of organisms. It also plays a large part in the amount of dissolved oxygen in the water.)

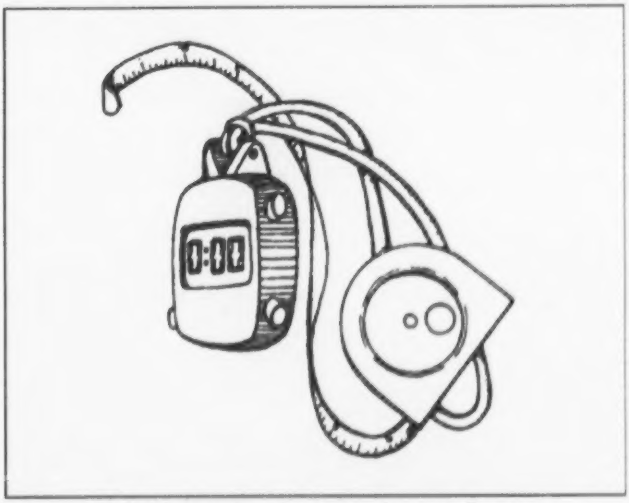


Figure 5–6 Measuring the rate of water flow

a. Measure and mark with stakes a distance of 30 meters along the path of the waterway.

b. Throw an orange or a ball into the water above the upstream marker. Using a stopwatch, measure the time in seconds it takes to reach the downstream marker.

c. Find the rate of flow by dividing the distance by the time the orange took to cover it.

Distance (m) ÷ Time (sec) = Rate of flow (m/sec)

d. Record the rate of flow.

5. Repeat procedure 4 at places where water appears to be moving at different rates. Record your data.

6. Prepare a report on the data your group collected to share with the rest of the class.

TEAM B. DISSOLVED SUBSTANCES

Acid rain is caused by sulfurous acids and nitrous acids in the upper atmosphere. These acids form when sulfur oxide gases or nitrogen oxide gases dissolve in water. The acids fall in rain, snow, or fog. Figure 5–7 shows the major sources of these gases.

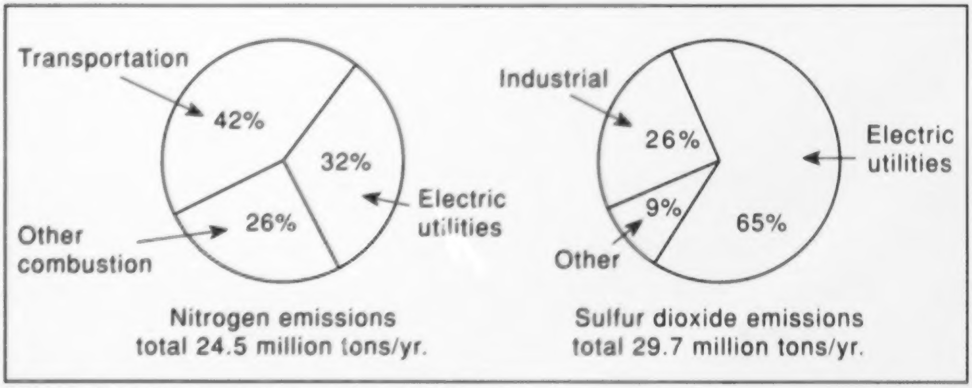


Figure 5–7 Sources of gases in acid rain

Sulfur oxides are produced mainly by coal-burning power plants and industrial boilers. Nitrogen oxides are emitted by automobiles and coal-fired boilers.

Acid rain kills animal life in lakes, affects the growth of plants, harms the respiratory system of humans, and damages buildings and statues.

Acid rain is not new. It used to be just a local problem in areas downwind from power plants and industrial sites. But the tall smokestacks that now send waste gases high into the atmosphere have made acid rain a problem in many places. Rain falling in the eastern United States and Canada, for instance, is 10 to 100 times more acidic than it was 20 or 30 years ago. The map in Figure 5–8 shows areas of the United States now affected by acid rain.

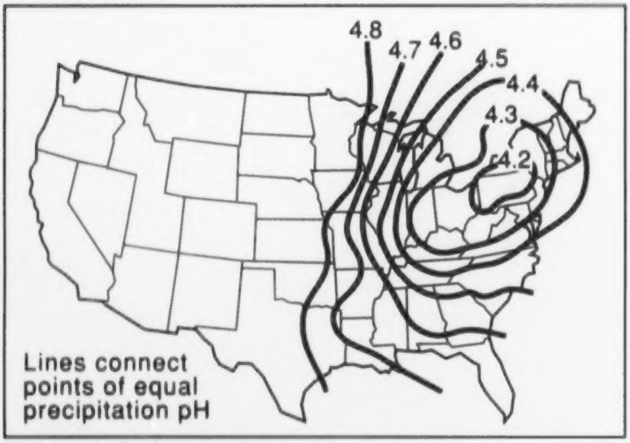


Figure 5–8 Areas affected by acid rain

Acid is measured on a *pH scale* ranging from 0 to 14. A reading of 0 is extremely acid; 14 is extremely alkaline, or basic; 7 is considered neutral. The smaller the number, the greater the acidity. The larger the number, the greater the alkalinity.

The pH scale is designed so that a change of 1 unit represents a tenfold change in acidity. For example, pH 5 is 10 times as acid as pH 6; pH 4 is 100 times as acid as pH 6. Natural values of pH in freshwater systems are commonly between 5.5 and 8.0. Acid rain and other sources of acid can change the pH of water systems, thereby altering their chemical and biological balances. Figure 5–9 shows the effects of various pH levels.

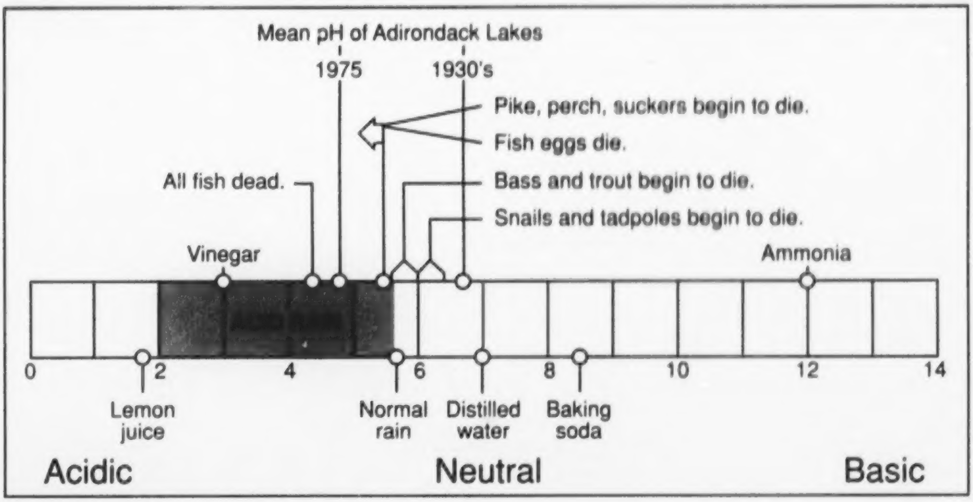

Mean pH of Adirondack Lakes
1975
1930's
Pike, perch, suckers begin to die.
Fish eggs die.
All fish dead.
Bass and trout begin to die.
Snails and tadpoles begin to die.
Vinegar
Ammonia
0
2
4
6
8
10
12
14
Lemon juice
Normal rain
Distilled water
Baking soda
Acidic
Neutral
Basic

Figure 5–9 The pH scale

Salinity

Salinity is a measure of the amount of salt and dissolved minerals in a water sample. It is an important property because it determines not only which life forms can live in the water but also affects its density. Recall from your studies of buoyancy and density in physical science that clean, fresh water has a density of about 1.0 g/mL, but a saturated Epsom salt solution has a density of about 1.2 g/mL. Recall the effect of density on the buoyancy of water.

Water with dissolved salts and minerals in it is not pure. Freshwater lakes, rivers, and streams all contain some dissolved matter. Water that is a mixture of fresh water and salt water is said to be *brackish.* Water with a very high salt content is called *brine.*

One of the most common methods for determining the salinity of a water sample is measuring its density with a *hydrometer*. Figure 5–10 shows a hydrometer calibrated for a range of densities from 1.00 to 1.06 g/mL.

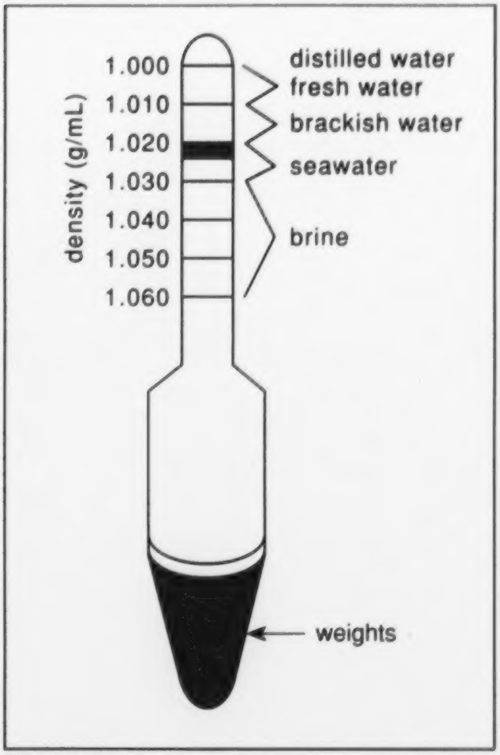

density (g/mL)
1.000
1.010
1.020
1.030
1.040
1.050
1.060
distilled water
fresh water
brackish water
seawater
brine
weights

Figure 5–10 An aquarium hydrometer showing the density range of water samples in g/mL

The higher the hydrometer floats in a water sample, the higher the water's salinity. The lower it sinks, the lower its salinity.

Materials

- pH indicator paper, wide-range
- several jars for water samples
- hydrometer
- watch or clock

Directions

1. Collect water samples from several places in the water study area. Label the samples so you know where each came from.

2. Use pH indicator paper to measure the acidity of the water samples. Chemicals in pH paper change color in the presence of acids and bases. A standard color chart supplied with the test paper shows the pH level.

    a. Immerse a piece of pH indicator paper in a sample of water.

    b. Observe the color change within the first 30 seconds.

    c. Compare the color of the pH test paper with the color chart supplied with the paper.

    d. Record the pH value of the sample.

3. Use a hydrometer to measure the relative salinity of the water samples.

    a. Put a water sample in a jar large enough to hold the hydrometer.

    b. Put the hydrometer in the water.

    c. Read the temperature. Record the density from the hydrometer.

d. Compare the hydrometer reading with the diagram in Figure 5–10. Record the salinity as

• fresh water	(density 1.00–1.01 g/mL)
• brackish water	(density 1.01–1.02 g/mL)
• seawater	(density 1.02–1.04 g/mL)
• brine	(density 1.04+ g/mL)

4. Add your data to the map of the water study area prepared by the Environment Team.

5. Prepare a report on the data your group collected to share with the rest of the class. Be prepared to explain the following:

a. The formation and effects of acid rain

b. How a hydrometer is used to measure salinity and how changes in salinity affect density and buoyancy

c. Why the temperature must be recorded when using the hydrometer to measure salinity

d. Your data on pH and the salinity of water samples

TEAM C. DISSOLVED GASES

Recall from Ecology Investigation 15, Major Gases in the Air, and Investigation 16, The Trace Components of Air, that air contains about 21% oxygen and 0.03% carbon dioxide by volume. These and other gases can be absorbed by water in a process called *aeration*. They can also enter water from the life processes of organisms in the water.

Dissolved oxygen is probably the most important gas for organisms living in water. Fish and other water organisms need dissolved oxygen for respiration. Most fish need a concentration of about 5 parts per million (5 ppm) of dissolved oxygen. Although some fish, such as trout, need more, and others, such as carp, can get by with less, most fish are sensitive to even slight reductions in dissolved oxygen. Only the most tolerant fishes can survive when the level of dissolved oxygen drops below 3 ppm.

The maximum of dissolved oxygen that water can hold, called the *saturation value*, varies with temperature. Table 5–11 shows the dissolved oxygen saturation values for various water temperatures. Any dramatic temperature increase that reduces the dissolved oxygen to less than about 3 ppm can kill fish.

Table 5–11 Saturation values for dissolved oxygen in fresh water at sea level

Temperature (°C)	Dissolved Oxygen (ppm)	Temperature (°C)	Dissolved Oxygen (ppm)
0	14.6	15	10.2
1	14.2	16	10.0
2	13.8	17	9.8
3	13.4	18	9.6
4	13.2	19	9.4
5	12.8	20	9.2
6	12.4	21	9.0
7	12.2	22	8.8
8	11.8	23	8.6
9	11.6	24	8.5
10	11.4	25	8.4
11	11.0	26	8.2
12	10.8	27	8.0
13	10.6	28	7.9
14	10.4	29	7.9

Dissolved carbon dioxide in water is also important to living things. Animals and plants produce carbon dioxide as a waste product from their life processes. Carbon dioxide also readily dissolves in water from the air and from natural processes. A high level of carbon dioxide in water usually corresponds to a low level of oxygen. Both harm living things. Polluted water is usually high in carbon dioxide.

Materials

- several jars for water samples
- water test kit for dissolved oxygen
- 250-mL beaker
- 2 medicine droppers
- 50 mL phenolphthalein solution
- 50 mL sodium hydroxide solution
- graduated cylinder
- watch or clock
- graph paper
- thermometer
- apron and goggles

Directions

1. Collect water samples from several places in the water study area. Divide each sample in two. Label the samples so you know where each came from.

CAUTION: Wear an apron and goggles.

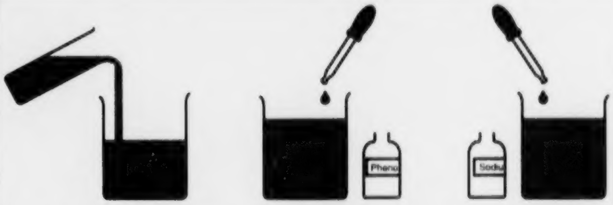
2. Using a water test kit, measure the relative dissolved oxygen concentration of each sample.

    a. Follow directions in the kit for testing dissolved oxygen. Since oxygen reactions occur continuously, you should test your samples in the field to get accurate, repeatable results.

    b. Measure and record the temperatures of the water samples.

    c. Graph the data on temperature and saturation levels for dissolved oxygen from Table 5–11.

d. Compare the data on dissolved oxygen in your water samples. How do they compare with the saturation levels for dissolved oxygen?



1. Pour out 100-mL sample of water.
2. Add 5 drops of phenolphthalein solution.
3. Add drops of sodium hydroxide solution until sample turns pink.

Figure 5–12 Testing for dissolved carbon dioxide

3. Measure the relative dissolved carbon dioxide in each water sample collected.

   a. Pour a 100-mL sample of water into a beaker.

   b. Add 5 drops of phenolphthalein solution to the water sample. Mix by swirling.

NOTE: If a light pink color appears in the water and remains after 1 minute, the water sample has no carbon dioxide in it. Record zero in your data table.

   c. If no pink color forms, add sodium hydroxide solution to your water sample one drop at a time. Swirl after adding each drop. Count the drops of sodium hydroxide solution needed to turn the water light pink.

NOTE: A light pink color may form, then disappear in a few seconds. Continue adding drops of sodium hydroxide solution until the water stays pink.

d. Using the rating scale below, read and record in your data table the number of drops used and the relative dissolved carbon dioxide.

0 drops	No carbon dioxide
1–5 drops	Low carbon dioxide content
6–10 drops	Medium carbon dioxide content
11+ drops	High carbon dioxide content

4. Add your data to the map of the water study area prepared by the Environment Team.

5. Prepare a report on the data your group collected to share with the rest of the class. Be prepared to explain the following:

   a. The importance and the effects of dissolved gases in water

   b. How you performed the tests

   c. Your data on dissolved oxygen and carbon dioxide in the water samples

TEAM D. NUTRIENTS

Plants and animals cannot grow without nutrients in the form of *nitrates* and *phosphates*. These two substances, along with *potassium*, are the major ingredients of commercial fertilizers. Nitrates and phosphates are important in water quality because excess amounts stimulate the growth of *algae*. Large growths of algae, called *blooms*, can clog streams and lakes and reduce oxygen levels at night, making the water unsuitable for many water animals.

Nitrates

Nitrates appear in water systems from the actions of some kinds of bacteria, from animal wastes, from septic tank breakouts, and from fertilizer runoff from farmlands, gardens, and lawns. Nitrates can also form when electrical storms convert nitrogen and oxygen in the air into nitrogen dioxide. This gas combines with rainwater to form nitric acid rain, which reacts with soil minerals to produce nitrates.

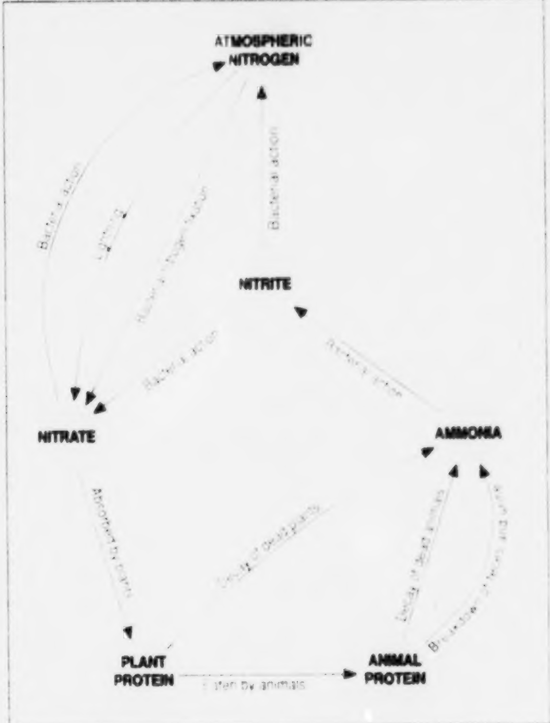

ATMOSPHERIC NITROGEN
Bacterial action
Lightning
Bacterial nitrogen fixation
Bacterial action
NITRITE
Bacterial action
Bacterial action
NITRATE
AMMONIA
Absorbed by plants
Decay of dead plants
Decay of dead animals
Breakdown of feces and urine
PLANT PROTEIN
Eaten by animals
ANIMAL PROTEIN

Figure 5–13 Formation of nitrates

High nitrate levels are especially dangerous in drinking water for infants under 6 months. Chemical reactions in the infant's stomach reduce the blood's capacity to carry oxygen. A shortage of oxygen can result in methemoglobinemia, or "blue baby" syndrome, which in extreme cases can kill the baby. Nitrate levels of 10 ppm or higher are dangerous.

BEST COPY AVAILABLE

Phosphates

Phosphates enter water systems from contact with high-phosphate soils, from phosphate-based detergents, and from runoff from farms, gardens, and lawns. Phosphate concentrations are high in wastewater from homes and industries.

Most natural waters contain .01 to .05 ppm of phosphate. In weak wastewater the average concentration is 5 ppm, in medium wastewater 15 ppm, and in strong wastewater 30 ppm. The phosphate concentration of domestic wastewater can be reduced, but the treatment is so expensive that it is rarely used.

Materials

- several jars for water samples
- nitrate and phosphate test kit
- apron and goggles

Directions

1. Collect water samples from several places in the water study area. Divide each sample in two. Label the samples so you know where each came from.

CAUTION: Wear an apron and goggles.

2. Using a test kit available from chemical suppliers, measure the relative nitrate concentration of each sample. Follow directions in the kit for the test for nitrates.

3. Measure the relative phosphate concentration in each water sample.

4. Add your data to the map of the water study area prepared by the Environment Team.

5. Prepare a report on the data your group collected to share with the rest of the class. Be prepared to explain the following:

   a. The importance and effects of nitrates and phosphates in water

   b. How you performed the tests

   c. Your data on dissolved nitrates and phosphates in the water samples

TEAM E. SUSPENDED SOLIDS

A highly productive water system—one with a high capacity for supporting life—is said to be *eutrophic.* Eutrophic water usually results in choking or suffocating algae blooms that threaten animal life by depleting the oxygen in water. An *oligotrophic* system has low productivity and fertility. Measures of *total suspended solids* (TSS) and *turbidity* determine the productivity of water.

Suspended solids in water consist primarily of silt, industrial wastes, human and animal wastes, decaying plant and animal matter, and living and dead *phytoplankton* and *zooplankton.* The quantity of total suspended solids is the weight of material suspended (not dissolved) in a volume of water.

It is difficult to set standards for TSS. Locally established *norms* are averages of measurements over several years. Wide deviations from local norms usually signal problems. Values below the norm may signal low productivity; values above the norm may signal high productivity.

Closely related to TSS is *turbidity.* A turbidity reading tells how much light passes through water. Because water containing suspended material absorbs and scatters light rays instead of transmitting light in a straight line, a turbidity reading can indicate total suspended solids.

Turbidity in groundwater or surface water shows that solids may be present. Because solids can harm health, turbidity must be kept low.

Materials

- several 1-L jars for water samples
- balance
- funnel
- filter paper
- flashlight

Directions

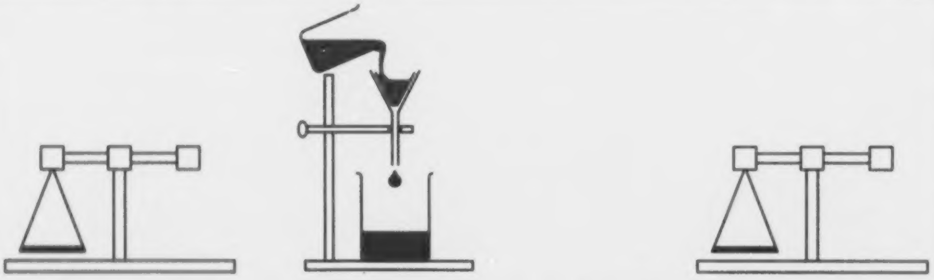
1. Collect 1-L samples of water from several places in the water study area. Label the samples so you know where each came from.

2. Measure the total suspended solids in each water sample.

   a. Measure the mass of a clean, dry filter paper on a balance. Measure to the nearest .01 g.

   b. Put the filter paper in a funnel. Filter a 1-L sample of water through the filter paper.

   c. Dry the filter paper completely.



a. Measure mass of dry filter paper.

b. Filter 1-L sample of water.

c. Dry filter paper.

d. Measure mass again.

Figure 5–14 Measuring total suspended solids

d. Measure the mass of the filter paper again. The difference in mass between the first and second measurements is the mass of the total suspended solids in 1 L of water. TSS values are commonly reported in milligrams per liter (mg/L). Record your TSS value.

e. Find out the TSS for the water area you are studying from local officials who monitor water quality.

3. Measure the relative turbidity of each water sample.

   a. Swirl the water sample to keep all the solid matter suspended. Shine a light through a jar containing the water sample. Use the same jar for each water sample.

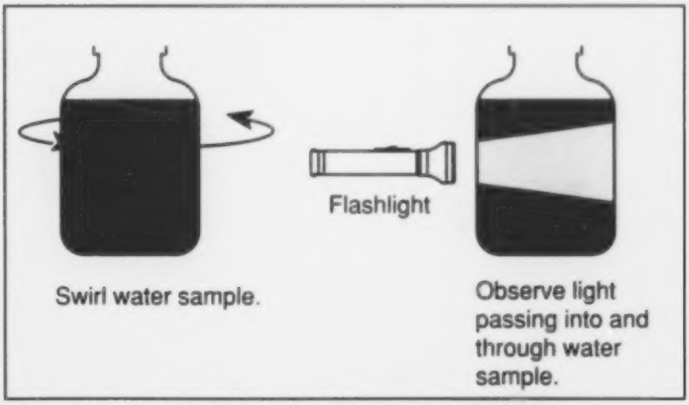

Flashlight
Swirl water sample.
Observe light passing into and through water sample.

Figure 5–15 Testing a water sample for turbidity

   b. Observe the scattering of light rays as they pass into and through the water sample.

c. Rate the turbidity using this scale:

0	No turbidity	Light passes through without scattering.
1	Low turbidity	Light passes through with slight scattering.
2	Some turbidity	Obvious absorption and scattering of light rays.
3	High turbidity	Light rays absorbed or highly scattered. Little or no light passes through.

d. Record your data.

4. Add your data to the map of the water study area prepared by the Environment Team.

5. Prepare a report on the data your group collected to share with the rest of the class. Be prepared to explain the following:

   a. The importance and the effects of suspended solids in water

   b. How you performed the tests

   c. Why you used the same equipment in each test

   d. Your data on dissolved suspended solids in the water samples

TEAM F. LIVING ORGANISMS

The abundance and variety of organisms living in and around water systems give clues to the quality of the water. Carefully observe the kinds of plants growing around the water in your study area. Are there long grasses? Reeds? Cattails? What kinds of plants are growing in the water? Do they resemble aquarium plants you have seen? Are there water lilies? Do plants grow in shallow water or deep water? What kinds of animals, fish, and insects can you see? Smell the air. What kinds of odors can you detect?

Some forms of life are so tiny that they can be seen only through a microscope. Microscopic living things swimming or drifting in water are generally called *plankton*. Microscopic plants are called *phytoplankton;* microscopic animals are called *zooplankton*. Plankton are important foods for many water animals.

Even smaller than plankton are *bacteria*. Bacteria can be *pathogenic* (harmful) or *nonpathogenic* (not harmful). Any body of water naturally contains some bacteria. It is when the bacteria count is high that we worry. When people swim or surf or water ski, their skin, eyes, ears, and nasal passages are exposed to bacteria. Drinking or accidentally swallowing some impure water also introduces bacteria into the body.

Water can become contaminated with large numbers of harmful bacteria when septic tanks fail, animal wastes are not properly managed, or municipal sewage is not properly treated. The harmful bacteria in these wastes come primarily from human and animal *feces*. Healthy humans and animals all contain some pathogenic and nonpathogenic bacteria.

Pathogenic bacteria in large numbers pose a health risk. The most common illnesses caused by swimming in contaminated water are infections of the eye, ear, skin, and nasal passages. Mild stomach illnesses are also common. More serious waterborne diseases such as typhoid and cholera are rare in the United States because state and federal governments require that almost all discharged wastewater be disinfected by chlorination.

Materials
- several jars for water samples
- plankton tow net
- hand lens or microscope
- water-bacterial pollution kit
- apron and goggles

Directions

1. Observe and describe the plants and animals living in the water and on land in the water study area. Use a data table similar to Table 5–16 to organize and record your observations.

Table 5–16 Observations of living things in the water study area

Location Number	Water or Land	Average Depth	Type of Plants	Number of Different Kinds of Plants	Type of Animals	Number of Different Kinds of Animals

2. Conduct odor tests on samples of water.

   a. Collect water samples from several places in the water study area. Use glass jars, not plastic ones. Label the samples so you know where each came from.

b. Shake the sample. Open the jar and sniff lightly. Disagreeable odors in water often come from decaying plant and animal matter, decomposition of sewage, industrial wastes, or by-products of the life processes of microscopic living things.

c. Record the code letters from Table 5–17 that best describe the odor.

Table 5–17 Qualitative descriptions of water odor

Code	Odor
A	Spicy
B	Cucumber-like
C	Flowery
D	Geranium-like
E	Sweetish
F	Industrial/chemical
G	Chlorine
H	Petroleum
I	Medicinal
J	Rotten eggs
K	Disagreeable
L	Fishy
M	Pigpen
O	Sewage
P	Damp earth
Q	Peaty
R	Grasslike
S	Rotten straw
T	Moldy, damp cellar

3. Get or make a plankton tow net.

a. Refer to the reference booklet "Sampling Methods" for information on making and using a plankton tow net.

b. Collect samples of plankton from the water study area.

   c. Observe the plankton through a hand lens or microscope.

   d. Describe and record the kinds of organisms you find.

CAUTION: Wear an apron and goggles.

4. Determine the bacterial count of water samples from the water study area.

   a. Collect several samples of water.

   b. Obtain a water-bacterial pollution kit. The kit has all the materials. Follow the directions for preparing the test.

   c. Incubate the bacteria cultures. Count the colonies that result. Record your data.

5. Add your data to the map of the water study area prepared by the Environment Team.

6. Prepare a report on the data your group collected to share with the rest of the class. Be prepared to explain the following:

   a. The importance and effects of living things, including plankton and bacteria, on the quality of water

   b. How you performed the tests

   c. Your data on living things in the water samples

6. PURIFYING WATER

Background

In Investigation 1, The Water Cycle, we learned that water is recycled over and over again. In fact, we still have about the same amount of water on Earth as we have always had. It has been reused many times.

But the water is not always clean. Substances from many sources can contaminate the water, making it unfit for our uses. Table 6–1 summarizes information on major water pollutants.

In wastewater in streams and reservoirs, contaminants are broken down into smaller components by such organisms as bacteria, worms, snails, and one-celled animals. The smaller components are then used as nutrients by algae and water weeds to grow and reproduce.

The process of breaking down matter in wastewater and then using the products to make new living tissue is called *assimilation*. Nearly every stream or reservoir can assimilate some wastewater without harming the living things in the water. However, when there is more waste in the water than living things can assimilate, the water is said to be *polluted*.

The average person in the United States uses about 150 gallons of water a day and produces about 120 gallons of wastewater or sewage. What happens to this water that disappears down the drain?

Table 6–1 Water pollutants and their effects

Pollutant	Source	Detrimental Effect
Plant and animal waste	Wastewater treatment; farm animals; nonpoint source runoff	Can kill aquatic life
Bacteria and viruses	Leakage from septic tanks on porous soils or high water tables; sewage treatment plants; boat discharges; animal feedlots; urban runoff	Contaminates shellfish, causing human diseases when consumed; contaminates groundwater and surface water, causing disease when it is consumed or infection when it is used for swimming or bathing
Nutrients	Agricultural, horticultural, and urban runoff; discharges from industries and boats; sewage treatment plants; septic tanks; animal feedlots	Nutrient enrichment results in algae blooms, causing eutrophication; algae blooms deplete oxygen, killing fish; eutrophication causes some fish diseases
Sediment	Land clearing; dredging; erosion	Clogs waterways; covers habitats and smothers organisms; causes turbidity, shading out plants and altering food chains
Fresh water	Water runoff; land clearing; floods; draining wetlands; channeling streams	Changes salinity patterns, affecting habitats, killing or stunting juvenile organisms; lowers reproduction rates
Temperature	Factories; electric generating plants; urban runoff; sunlight on drought-lowered streams	Alters fish reproduction; reduces dissolved oxygen causing fish kills
Petroleum products	Fuel exhausts; motor oil and grease; power plant emissions; industrial discharges; spills and dumping; leaking underground storage containers; urban runoff	Spills kill aquatic life, damage beaches, destroy wetlands; runoff is toxic to marine organisms, causing death, disease, and reproductive problems
Chlorine	Water treatment plants; swimming pool backwash	Kills aquatic life
Heavy metals (copper, zinc, lead, cadmium, mercury)	Fuel and exhaust from motorboats and automobiles; industrial emissions/effluent; landfill wastes; urban runoff; natural deposits in soils; hazardous waste spills/ disposal	Accumulates in fish tissues, causing disease, brain damage, birth defects, miscarriages, and infant deaths when eaten by humans
Toxic waste	Forestry, urban, and agricultural runoff; industrial and municipal effluent; spills or dumping	Causes cancer, birth defects, and chronic illness when consumed in contaminated water or affected seafood

Problem

1. What happens to our wastewater?

2. How can contaminated water be purified so that it can be reused safely?

Materials

- samples of contaminated water
- graph paper
- apron and goggles
- other materials needed for experimental designs

Procedure

1. Divide the class into groups of three or four.

2. Find out what happens to the sewage from your school and your community.

    a. Choose one of the investigations in Table 6–2. The same investigation may be done by more than one group, but all investigations should be completed.

    b. Carry out your investigation.

Table 6–2 Sewage treatment investigations

Group Number	Investigation
1	Find out where wastewater from your school goes. Make a scale drawing of the wastewater system in your school. Look for such evidence of the sewer system as manhole covers, drains, and gutters. Post the drawing.
2	Find out where the wastewater from your community goes, what kind of treatment it gets, and where it is dumped. Report to the class.
3	Find out about primary treatment of sewage, what processes and organisms it uses, and how pure the treated water is. Report to the class.
4	Find out about secondary and tertiary wastewater treatment, what processes and organisms it uses, and how pure the treated water is. Report to the class.
5	Find out how a septic tank works, what processes and organisms it uses, and how pure the resulting water is. Report to the class.

3. Design a way to purify a sample of water.

   a. Develop a plan in your group. Write out the plan. Include a flow diagram. List the materials you will need.

   b. Have your plan approved by your teacher for safety. Your teacher will give your group a sample of contaminated water.

CAUTION: Wear an apron and goggles.

   c. Carry out your plan. Measure the pure water you get. Measure the time the process takes. Record the results. Share your plan and results with other groups.

Summary

1. What kinds of treatment is sewage given in your community?
   a. Where is sewage from your school and community treated?
   b. Which level of treatment (primary, secondary, or tertiary) is best for your community? Why?
   c. How does a septic tank work to treat sewage?
   d. What effect would absorption, percolation, and capillarity of water in soil have on the operation of a septic tank?

2. If the average person produces 120 gallons of sewage a day,
   a. How much sewage does a person produce in a year?
   b. How much sewage does your school produce in a day? In a year?
   c. How much sewage does your community produce in a day? In a year?
   d. How does the national average of sewage produced by one person compare with your estimate of your own water use in Investigation 2?

3. Prepare a summary report of wastewater treatment in your community. Share your report with students in other schools, states, or countries.
   a. Find out how sewage treatment is alike and different in other communities.
   b. Which wastewater problems or issues in other communities are similar to those in your community? Which are different?

🔑4. Share the results of your water-purifying designs with the class.

   a. Explain how you purified your contaminated water sample. Tell how much purified water you got and how long it took to get it.

   b. Make a bar graph of the quantities of purified water obtained by each design.

🔑5. Is your sample really pure? How can you tell?

   a. What does "pure" mean?

   b. Would you drink your "pure" sample? Why or why not?

6. Compare natural and technological systems of purifying water.

   a. How is water purified naturally? List the ways.

   b. How are wastewater assimilation in a stream or reservoir and wastewater treatment in a sewage treatment plan similar? How are they different?

   c. What happens to treated sewage water dumped from a sewage treatment plant?

Challenge

1. In some parts of the world desalination is used to make fresh water.

   a. Find out how much water costs in your community.

   b. Find out how much desalinated water costs.

   c. Why is desalination not widely used to produce fresh water?

2. Arrange to visit the sewage treatment plant in your community. Identify the parts of the treatment system.

3. Invite a person from the agency responsible for sewage treatment in your community to speak to your class.
    a. Ask the person to explain the operation of the sewer system and the treatment plant.
    b. Be prepared to ask questions about wastewater management in your community.
4. In what ways could you reduce the amount of sewage you produce each day?
    a. Make a plan to reduce your sewage by 10%.
    b. Decide how following your plan would affect your lifestyle.
    c. Try out your plan.
    d. In class discuss other ways to conserve water and reduce sewage.

7. MANAGING WATER RESOURCES

Background

Water is a vital resource. But who owns it? And who is responsible for ensuring its quality?

Several bodies of law determine who has a right to use our nation's water. Federal laws take top priority. But much of the land is controlled by states or cities, so they determine who may use most of the water. The policies of industry and the habits of people also determine how water is used.

Water User Rights

During the 200 years of our history, four important legal principles about the rights to use water have evolved in the United States. The states have built their legal systems of water rights on one or more of these four principles:

> *Riparian or Common Law Rights.* The person who owns the land above a water source has absolute ownership of underlying groundwater and may use it with no limits on the amount.
>
> *Reasonable Use Rights.* This rule restricts the right to "reasonable" use of water. A landowner's right to use water is limited only when the water supply is not adequate to meet immediate demands.
>
> *Appropriation Rights.* This rule is "first come, first served." The people who used the water first have the strongest claim to the water supply when it is limited. This rule could stop the drilling of new wells in areas that are considered fully developed.
>
> *Correlative Rights.* All landowners have the same rights to the groundwater they need to supply their lands on top of the water supply. If too many are trying to use the water supply, the courts decide how to divide it. This rule can lead to lengthy and costly legal battles.

Other rights, known as overriding rights, can take priority over the four legal principles of water rights used by the states.

Overriding Rights include

- federal rights to water for land reclamation and conservation
- Indian reserved rights for Indian reservations
- Pueblo rights to communal water supplies in former Spanish territories
- federal rights to water needed for national security

Government Agency Roles

Governments not only determine who may use water; they also monitor the quality of water. Both federal and state governments pass laws setting up agencies to make and enforce regulations on water quality. County and city governments also pass laws or codes to control water quality in their jurisdictions.

Two kinds of government agencies manage water quality. The first kind is *regulatory agencies,* which enforce laws dealing with water quality, disposal of wastes, and wastewater treatment. Examples of such agencies are the federal Environmental Protection Agency, state departments of health, state departments of environmental management, and county and city agencies that grant permits and inspect water systems.

The second kind, *nonregulatory agencies,* manage, develop, and monitor natural resources. These agencies rarely have authority to enforce water quality laws, but they usually work closely with regulatory agencies to protect and improve water quality. Examples are the Tennessee Valley Authority, the Bureau of Reclamation, and the Soil Conservation Service. At the local level there are sewage and water supply boards. These agencies collect data on water resources, conduct research, build and operate reservoirs, promote conservation of resources, and participate in activities related to water quality management.

Federal and state agencies share responsibility for water quality in several ways. Federal agencies often set standards and write regulations that are enforced by state regulatory agencies. State agencies determine the amount of wastewater treatment required of cities or industries to protect quality in streams and lakes. Cities and industries collect water samples, test them, and submit monthly reports to the state agencies to show whether the level of treatment is consistent and sufficient to prevent pollution.

Federal Legislation

Our national concern for clean, fresh water is reflected in a long history of federal legislation. The first federal law to protect the nation's waters from pollution was the Rivers and Harbors Act of 1899. Stronger legislation was passed in 1948. Under this law, the states retained primary responsibility for water quality standards and management. The federal government supplied money for research. The law provided only weak punishments for offenders.

During the 1960s, amendments provided for federal water quality standards, federally approved state standards, and increased funding for research. However, as water pollution increased in many areas of the country, public concern led to two more important environmental laws.

The National Environmental Policy Act of 1969 set the stage for all environmental protection laws that followed. In response to this act, the states created or strengthened their own water quality or water resource agencies. The act also required environmental impact statements for all major activities that might damage the environment.

The federal Water Pollution Control Act (Clean Water Act), passed in 1972 and amended in 1977 and 1987, is the basis for most current water quality regulations. Other federal laws that deal with water quality are the Safe Drinking Water Act passed in 1974 and amended in 1977 and 1986, the Toxic Substances Control Act passed in 1976 and amended in 1984, and the Surface Mining Reclamation and Control Act passed in 1977.

Shifting Emphases

Major changes of role are unlikely in water management. But as point sources of pollution come under control, attention is shifting to nonpoint sources. The Clean Water Act of 1972 had only weak provisions for nonpoint sources because there were few practical methods of controlling them. Now nonregulatory agencies are working to develop, demonstrate, and promote practical techniques for controlling nonpoint sources.

The Personal Dimension

Water conservation is the practice of using water resources efficiently and protecting them from pollution. Wise use of our water resources has become more and more important as demands from industries and cities mount. The costs of distributing water and treating wastewater are rising steadily. It is becoming more urgent that each of us develop good water-conservation habits. An abundant supply of clean water is essential for public health and economic growth.

Problem

How are water resources managed in my community?

Procedure

1. Divide the class into groups of three or four. Decide which group will take responsibility for fact-finding in procedures 2–6 below.

2. Find out what principles of water rights determine water use in your state. Prepare a report to the class.

3. Find out what groups *manage* the water supply and the sewage treatment facilities in your community. Prepare a report to the class.

4. Find out what groups *regulate* the water supply and sewage treatment facilities in your community. Prepare a report to the class.

5. Find out which citizens' groups in your area work on water resource management.

    a. Contact one or more of these groups. Find out what their concerns are and what they are doing about them.

   b. Collect information, brochures, leaflets, posters, and other materials from each organization.

   c. Invite a guest speaker from one of the organizations to tell the class about water conservation.

6. Find out what individuals and groups can do to conserve water.

7. Develop a class water-conservation code. Prepare a list of rules to live by to practice water conservation.

8. Discuss the code in class. Then revise your rules as necessary.

   a. List reasons for each rule.

   b. After the discussion take a vote on adopting the code.

   c. Follow the rules in your water-conservation code for a month.

Summary

1. How do federal and state water use rights affect you as a user of water?

2. How do groups managing the community's water supply and sewage treatment affect you as a user of water?

3. How do groups regulating your community's water supply and sewage treatment affect you as a user of water?

4. How do federal and state water pollution laws affect you as a user of water?

5. How can following a conservation code benefit you and others?

6. What are the similarities and differences between rights, laws, and codes?

7. Do you agree or disagree that "having enough quality water ultimately comes down to the decisions of individuals"? Why?

New Vocabulary for Section B

acid rain
aeration
algae blooms
assimilation
bacteria
brackish
brine
density
dissolved gases
eutrophic
hydrometer
nitrates
nonpathogenic
nonpoint source
nonregulatory agencies
norms
oligotrophic
pathogenic
pH
phosphates
phytoplankton
plankton
point source
pollutant
rate of flow
regulatory agencies
salinity
saturation value
sewage
source
total suspended solids
turbidity
wastewater
water conservation
water rights
zooplankton

8. PLANNING FOR THE FUTURE: A SIMULATION

Background

Welcome to Kaiholo, a wonderful place to live. Kaiholo, on our state's windward coast, has a unique environment—steep mountain ridges to the north and the ever-changing ocean to the south.

The dominant feature of the area is Wailana Marsh, covered by grasses, cattails, and other aquatic plants. The marsh is a nursery for hundreds of animals that spend their lives there or move into the ocean as adults. By holding vast amounts of runoff from the mountains during our frequent heavy rainfalls, it controls flooding in our community.

The Kaiholo community has grown rapidly in the last 30 years. Thirty years ago it was largely uninhabited. Only four vacation homes had been built. Wailana Marsh covered much of the area. Figures 8–1 through 8–4 show how the community has changed over the years.

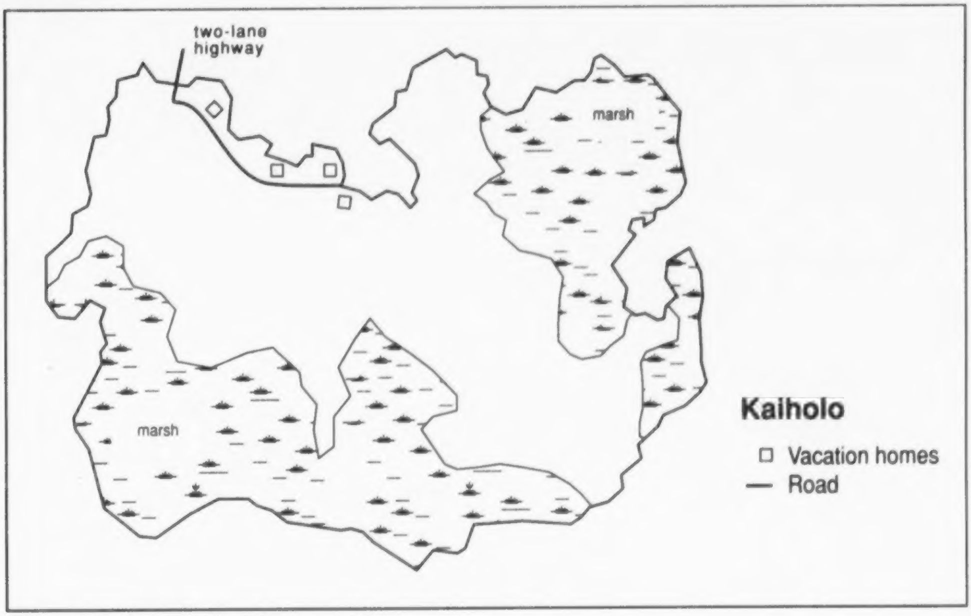

two-lane highway
marsh
marsh
Kaiholo
□ Vacation homes
— Road

Figure 8–1 Kaiholo 30 years ago

- A winding two-lane road over the mountains connected Kaiholo to other parts of the state.
- Four vacation homes formed a small community.
- The marsh dominated the area.
- The population was 42.

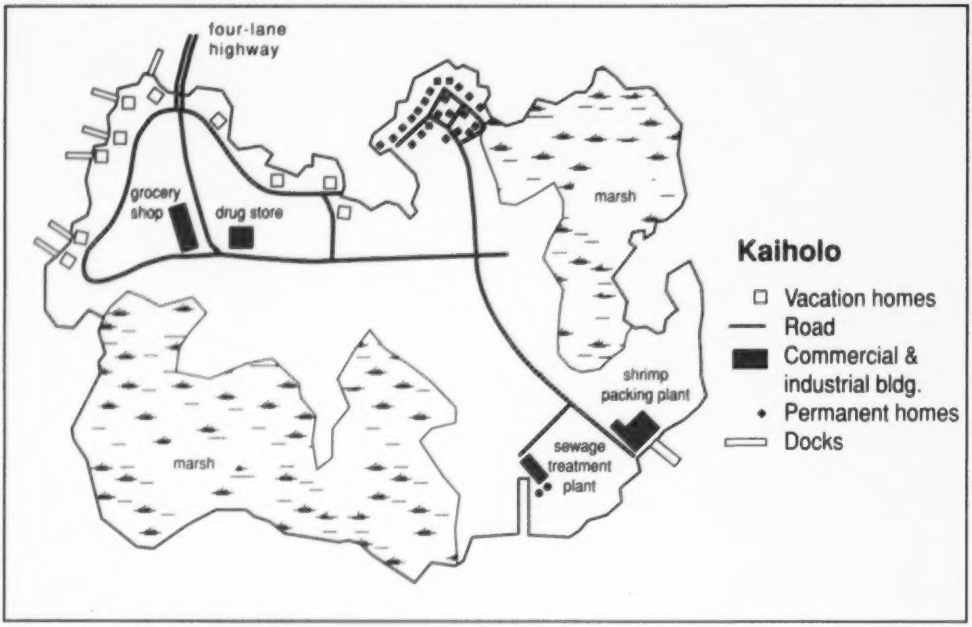

four-lane highway
grocery shop
drug store
marsh
marsh
shrimp packing plant
sewage treatment plant
Kaiholo
☐ Vacation homes
— Road
■ Commercial & industrial bldg.
• Permanent homes
▭ Docks

Figure 8–2 Kaiholo 20 years ago

- A four-lane highway tunneled through the mountains, connecting Kaiholo to other parts of the state.
- Travel time to Kaiholo was short.
- A housing development provided homes for workers in the community and commuters who worked outside.
- A shrimp-packing plant employed local workers.
- A sewage treatment plant used primary treatment to process wastewater.
- A supermarket and drug store served the needs of the community.
- The population was 5,523.

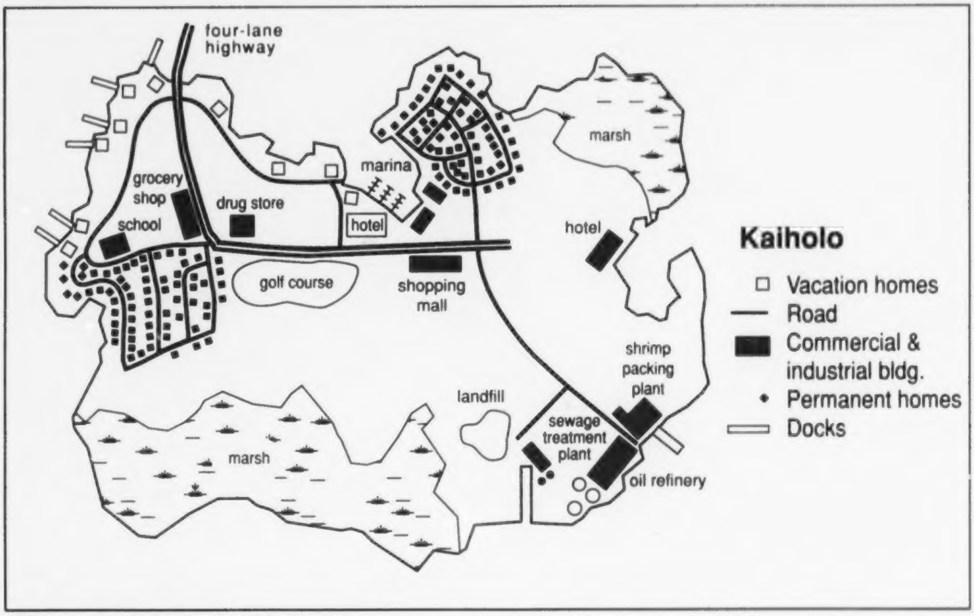

four-lane highway
grocery shop
drug store
school
marina
hotel
hotel
golf course
shopping mall
marsh
marsh
landfill
shrimp packing plant
sewage treatment plant
oil refinery
Kaiholo
☐ Vacation homes
— Road
■ Commercial & industrial bldg.
• Permanent homes
▭ Docks

Figure 8–3 Kaiholo 10 years ago

- The shrimp-packing plant expanded, employing more workers.
- More housing was built as the community grew.
- A sanitary landfill handled solid wastes.
- An oil refinery employed workers.
- A shopping mall served the growing community.
- Two hotels, a golf course, and a marina served the needs of tourists and the community.
- A new school provided education for youngsters.
- The population was 22,271.

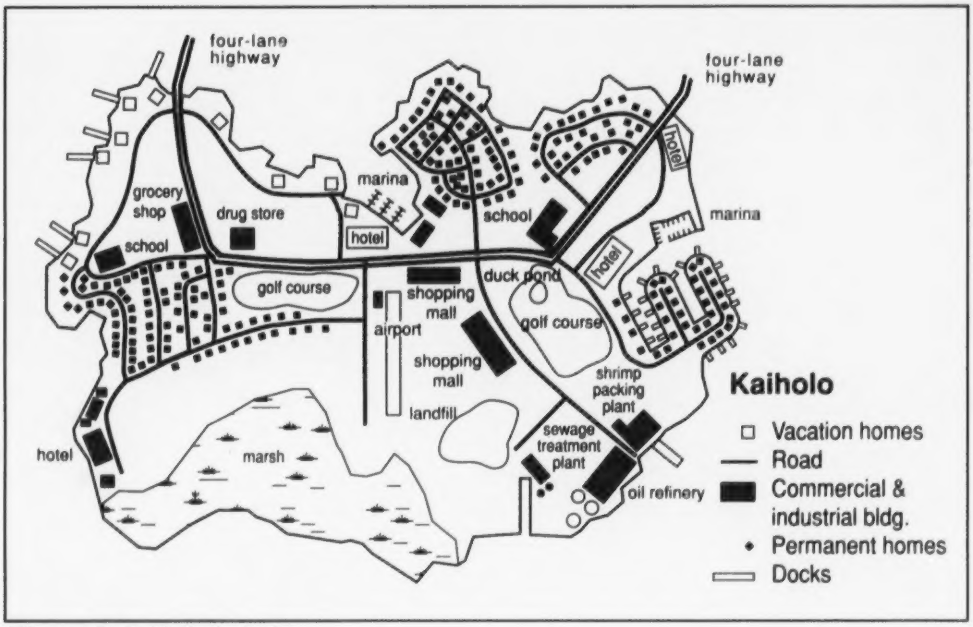

four-lane highway
four-lane highway
grocery shop
drug store
marina
hotel
school
school
golf course
shopping mall
airport
duck pond
golf course
hotel
hotel
marina
shopping mall
landfill
shrimp packing plant
sewage treatment plant
oil refinery
hotel
marsh
Kaiholo
□ Vacation homes
— Road
■ Commercial & industrial bldg.
• Permanent homes
▭ Docks

Figure 8–4 Kaiholo today

- A second four-lane highway makes travel to and from Kaiholo even easier.
- A small airport was recently completed.
- Two more hotel complexes, a public marina, and another golf course provide for the needs of an increasing tourist trade.
- The sanitary landfill was recently enlarged.
- A new housing development with boat ramps attracts fishermen and water enthusiasts.
- A second school is needed.
- A pond has been dredged on the golf course to attract migrating birds.
- The population is 57,836.

As you can see, our community has grown remarkably in 30 years. The demands of the population for space, water, and recreational facilities have grown with it. With all the building, Wailana Marsh has been greatly reduced in size. We now face new challenges.

The question now before the community is what to do with what remains of Wailana Marsh. Three proposals have been presented. A town meeting has been called to discuss the issue and to advise the city planning department. People representing many points of view have come to this meeting. They all feel very strongly about their positions.

Proposal 1. Drain the marsh. Create an expanded marina and housing complex. Channel the water into the ocean.

Proposal 2. Drain the marsh. Create a business, industry, and housing complex. Channel the water into the ocean.

Proposal 3. Leave the marsh as it is.

Activity

Help decide the future of Wailana Marsh.

Materials

- chart paper
- colored markers

Procedure

1. Examine the maps of Kaiholo in Figures 8–1 through 8–4.

   a. Look at Figure 8–1. What percentage of Kaiholo was marsh 30 years ago? How much is marsh now?

b. Look carefully at the amount of development.

   - How has transportation changed?
   - What industries have been added?
   - What recreational facilities have been added?
   - What public services have been provided to meet residential and industrial needs?
   - What impact do these public services have on water resources?
   - In what ways have people used the marsh? What have been the effects?
   - Why is the marsh important to Kaiholo?

2. Prepare to present a position, discuss the problems, and make decisions on the future of Kaiholo and its water resources. You may need to argue for a position that is not your own.

   a. Work with a partner or a small group.

   b. Your teacher will assign a role and position to each group. You and your partners will present the position.

   c. Read the role you are to play.

   d. Prepare a position statement to be given at a town meeting. Use the information you have been given and add information of your own. Try to convey the strong feelings associated with your position. Be ready to compromise.

3. Play out the simulation on the future of Wailana Marsh.
    a. Decide who will chair the meeting.
    b. Prepare a large map of present-day Kaiholo. Post it in the front of the room.
    c. Open the meeting by calling for testimony on all positions represented. Have each person tell what should be done with the remaining marsh and why.
    d. After the testimony, open discussion on the issue. Make lists or drawings of proposed uses of the marsh. At the end of the discussion, vote on the proposals.

Summary

🔑1. List the needs identified in the town meeting that you think are important. Rank them from most important to least important.

🔑2. What proposed developments, if any, were in the plan adopted? How will these developments affect water resource management in the community?

3. What proposed developments were not included in the adopted plan? Why not?

🔑4. Did you have difficulty finding a balance between development and conservation? If so, what were the problems?

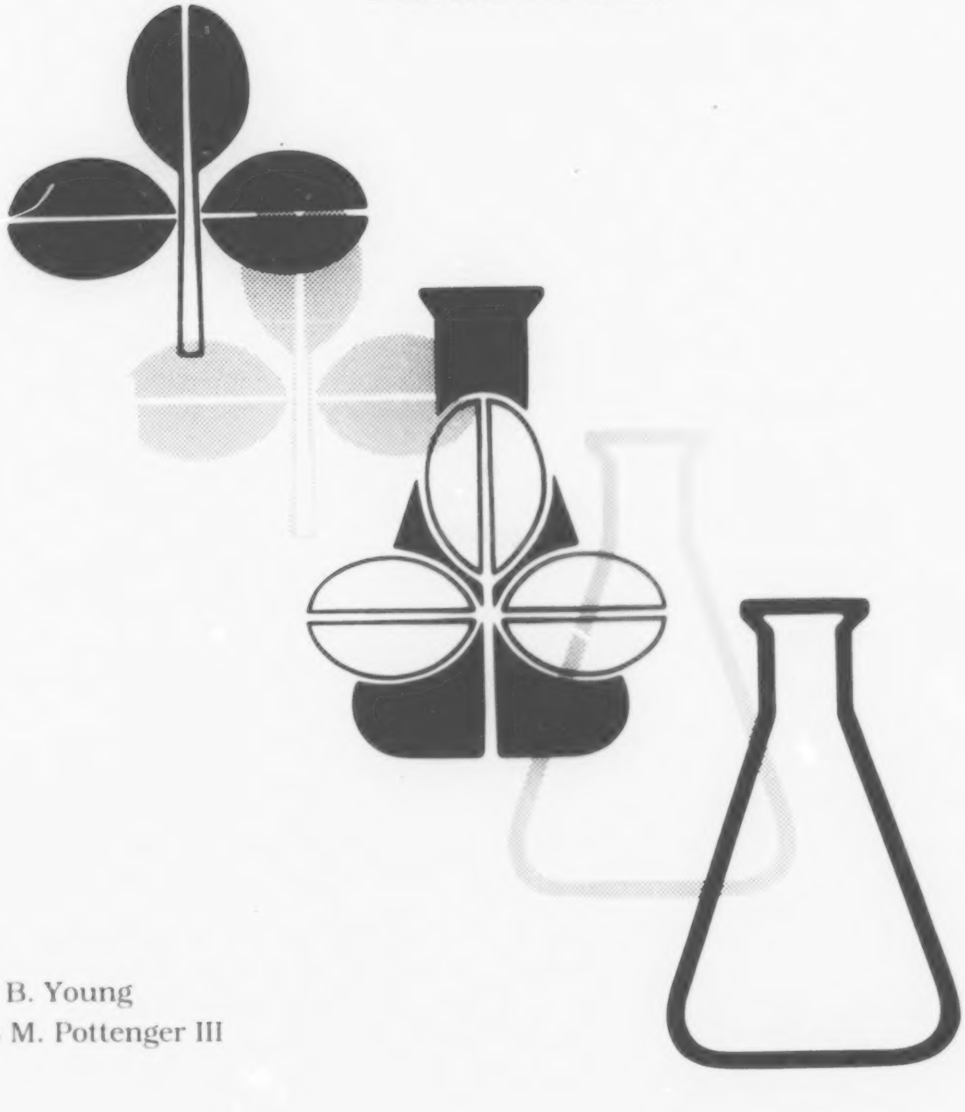
🔑5. Did you find cases in the planning process where the wishes or needs of a person or a small group became more important than needs of the whole community? Which cases? What compromises were made?

🔑6. How does this simulation relate to real-life situations in your community? Do some land and water issues parallel issues in this simulation? Which ones?

SE

Water Resource Management

Teacher's Guide



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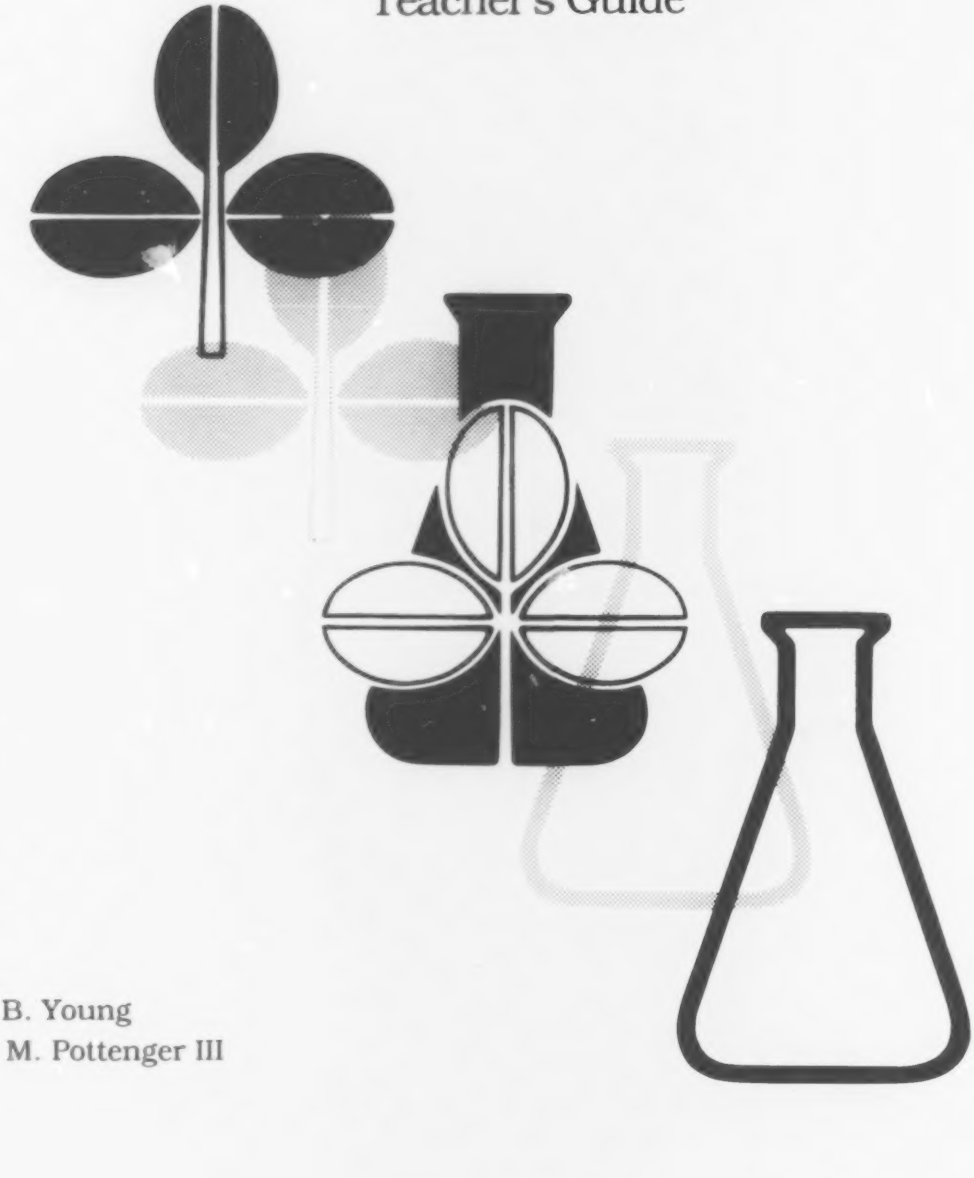
Water Resource Management

Teacher's Guide



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FAST
Foundational Approaches in Science Teaching
Curriculum Research & Development Group

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CONTENTS

ACKNOWLEDGMENTS iv

PREFACE v

INTRODUCTION vii

Theory and Practice in *FAST* vii

Conceptual Framework of *The Local Environment* xiii

FAST Instructional Materials xix

FAST 1 Safety Advisory xxvii

RATIONALE, OVERVIEW, REFERENCES 1

SECTION A. WATER IN MY COMMUNITY 3

1. The Water Cycle 5
2. Uses of Water 9
3. Distribution of Water 13
4. Local Issues 18

SECTION B. MONITORING WATER QUALITY 22

5. Testing Water Quality 24
6. Purifying Water 29
7. Managing Water Resources 37

SECTION C. MAKING DECISIONS 44

8. Planning for the Future: A Simulation 46

VISUAL AID MASTERS 55

STUDENT RECORD BOOK MASTERS 75

88

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PREFACE

The *Foundational Approaches in Science Teaching (FAST)* program is one of several curriculum development projects of the Curriculum Research & Development Group (CRDG) of the University of Hawaii. CRDG is a branch of the College of Education. The CRDG staff of about a hundred members conducts curriculum research and design, develops and evaluates educational materials, disseminates them, and offers training and follow-up services. CRDG programs serve children and youth at preschool, elementary-school, middle-school, and high-school levels. Its programs are tested and used in the University Laboratory School, in the schools of Hawaii, in selected schools in the Pacific Basin, and in the United States generally.

Members of the *FAST* staff have developed a series of interdisciplinary science courses that emphasize the foundational concepts and methods of the physical, biological, and earth sciences. By directly involving students in investigating events in their everyday environment and carrying out experiments to answer some of their questions, *FAST* courses give students a sense of how the modern scientific community operates. This process of inquiry and subsequent research is used throughout each course.

Students in *FAST* courses study several disciplines, including physics, chemistry, earth science, and biology. In addition, *FAST* includes study of the interrelationships among science, technology, and society in a component called the Relational Study. Thus, through an inquiry approach, these courses give students an understanding of both the concepts of science and their applications to the everyday environment.

Titles of the courses developed thus far are *The Local Environment*, *The Flow of Matter and Energy Through the Biosphere*, and *Change over Time*.

INTRODUCTION

THEORY AND PRACTICE IN *FAST*

FAST is based on a constructivist philosophy of learning. Among the constructivist assumptions are the beliefs that all learners construct their own knowledge and understanding from their experiences, that this knowledge development is incremental, and that the knowledge we hold in common is developed and clarified through interactions with others.

Translated into classroom practice, these beliefs mean that students in *FAST* engage in experiential, hands-on learning. Investigations are carefully sequenced and connected to previous experience both in school and out of school to enable students to build their knowledge. Further, *FAST* investigations are conducted in small collaborative groups who share data, ideas, and experiences. Class discussion following each investigation is essential to identify and clarify generalizations held in common.

A research team model is used for class organization in *FAST*. Group interaction in planning and executing investigations, discussing and validating hypotheses, and summarizing and drawing conclusions is central to the *FAST* instructional system. Instead of a disseminator of information, the teacher becomes a facilitator of group interaction and director of learning, maintaining an atmosphere of challenge, setting tasks, asking questions, giving suggestions for further investigations, and helping students evaluate their work and their competences. In many *FAST* sequences, students engage in the full scope of research activities. They must identify the kind of problem they are dealing with, formulate hypotheses, conduct experiments, and report their findings for critical review by their peers. Thus students become producers rather than receivers of information.

OBJECTIVES

FAST is designed to provide investigative experiences and inquiry activities in the physical, biological, and earth sciences as well as in the application of the knowledge of these sciences to environmental issues.

The goal of *FAST* is to develop scientifically literate students who have both the background necessary for understanding environmental concerns in our technological society and the foundational tools for further study in science.

The objectives of *FAST* are to increase students'

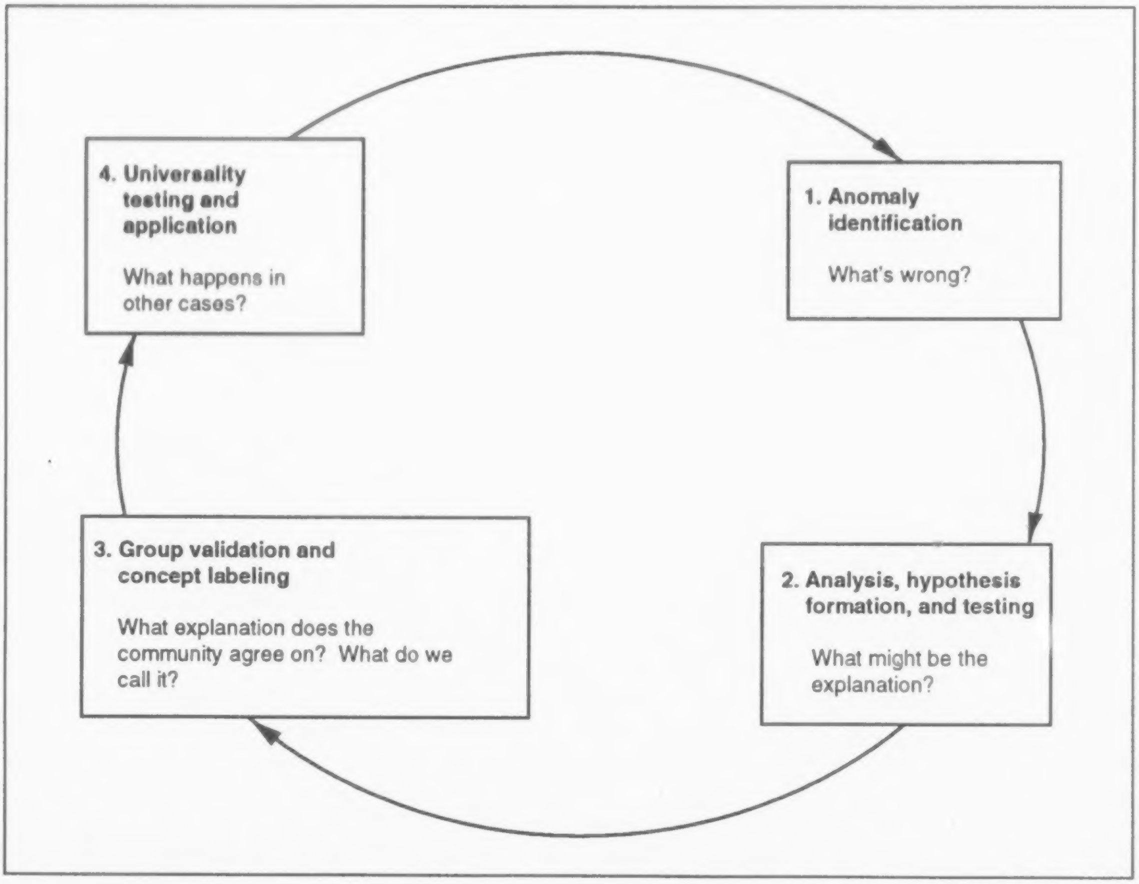
1. capability to perform basic laboratory skills.
2. capability to use the symbolic tools employed in science.
3. knowledge of concepts that are foundational to modern science.
4. capability to engage in scientific inquiry.
5. understanding of the sequential nature of the development of science.

6. understanding of the relationships among disciplines of science.
7. knowledge of the nature of science.
8. capability to apply scientific knowledge to other areas of endeavor.
9. understanding of the relationships among science, technology, and society.
10. capability to use scientific knowledge for making decisions.
11. internalization of the values, attitudes, and traits necessary for successful endeavor in science.

THE *FAST* INSTRUCTIONAL MODEL

FAST activities use a generalized instructional model based on normal research practices of science. In *FAST* the cycle begins with an activity that presents an anomaly—a puzzling situation—to engage students' curiosity and motivate inquiry. Next come opportunities for students to analyze the anomaly, develop an explanatory hypothesis, and test it. Successful hypotheses are validated in the class community, and new concepts are named. Finally students investigate the universality of the accepted explanation by testing it in applications. Often this sequence starts a new cycle of anomaly identification and further explanation.

***FAST* Instructional Model**


4. Universality testing and application
What happens in other cases?
1. Anomaly identification
What's wrong?
3. Group validation and concept labeling
What explanation does the community agree on? What do we call it?
2. Analysis, hypothesis formation, and testing
What might be the explanation?

DESCRIPTION OF *FAST* COURSES

FAST 1. The Local Environment

In the Ecology strand of this course, students investigate the local environment to find basic biological, geological, and meteorological interrelationships in natural systems. Concurrently, in the Physical Science strand, they develop the foundational concepts of matter, state change, and energy needed to explain physical aspects of the environment. The Relational Study strand draws together concepts and skills from the Physical Science and Ecology strands, applying them to the practical issue of how society can deal with an environmental hazard.

Topics and problems lend themselves to the development of basic principles of the physical and ecological sciences. Data, for the most part, point to specific conclusions. Students learn to handle data, design experiments, interpret results, and manipulate standard laboratory equipment. By the end of the course, typical students feel confident and bold in their approach to new laboratory problems.

FAST 2. The Flow of Matter and Energy Through the Biosphere

This course explores, in the field and laboratory, the transfer of matter and energy through ecosystems. Through their investigations, students learn that all living organisms are part of a complex, interdependent biosphere. In the Physical Science strand, they investigate the nature of light, search for evidence of an atomic structure of matter by analyzing and synthesizing compounds, and investigate the kinetic molecular model of matter. The activities in the Physical Science strand support the Ecology strand. The Ecology strand focuses on matter and energy transfers in ecosystems. As students investigate the processes of photosynthesis, respiration, and decomposition, they develop an understanding of the interdependence of all living organisms and the cycling of matter and the flow of energy in ecosystems. In the Relational Study strand, they apply their knowledge and skills by designing garden plots to maximize the yield of one or more products. They also engage in decision-making situations that require them to analyze such global problems as shortages of food or fossil fuel.

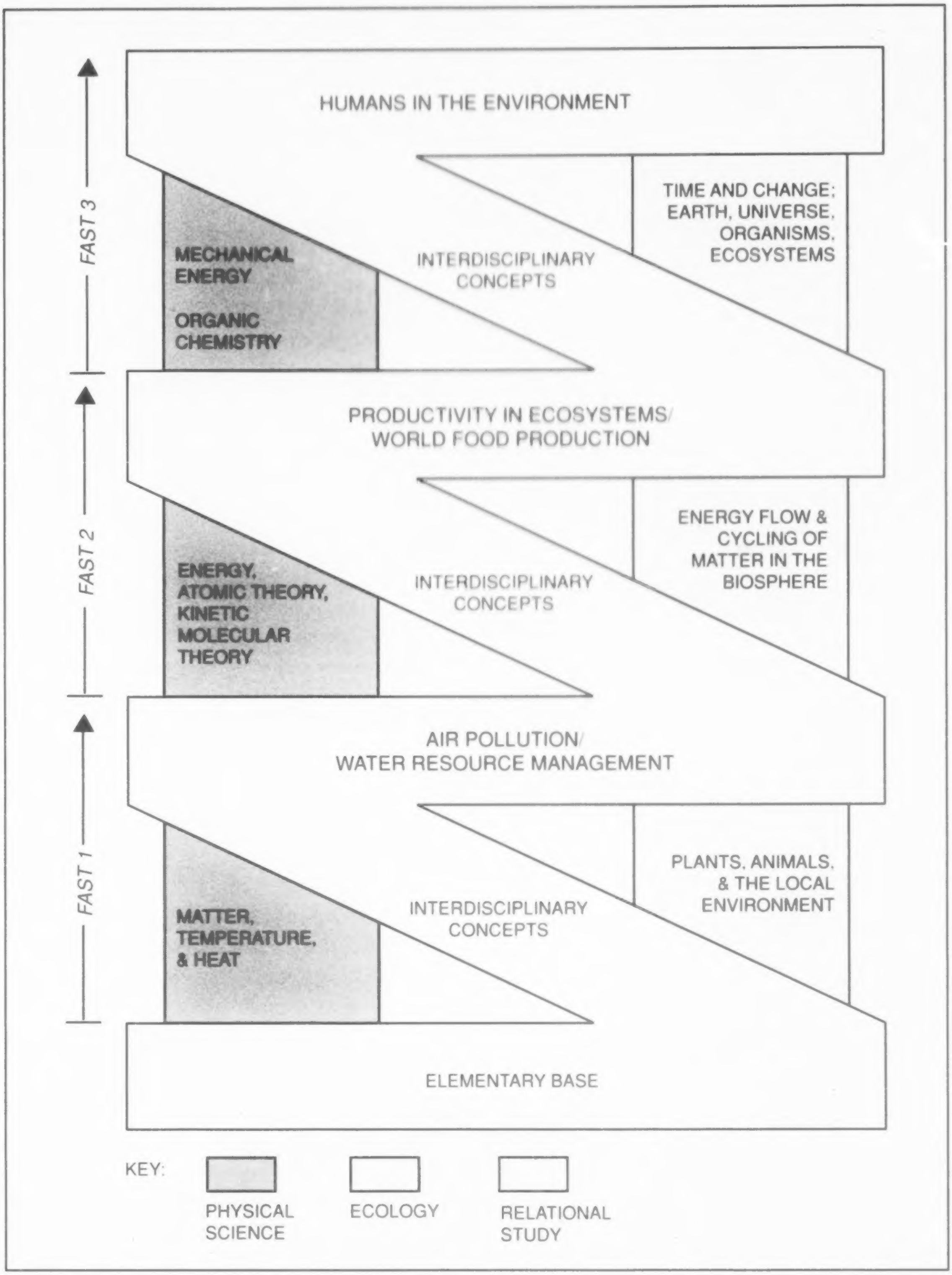
FAST 3. Change over Time

Change over Time relates the concepts of physical science, earth science, and biological science through the study of changes in the earth, the solar system, and the universe. Students begin by measuring force, gravity, work, and energy in laboratory investigations. These concepts are basic to interpreting interactions of matter and energy, which students study in investigations of mountain formation, weathering, and erosion. They are also important in understanding theories of the origin and structure of the universe, stellar evolution, the formation of the earth, and plate tectonics.

Students develop an operational definition of *life* and identify the structure of organic molecules characteristic of life. They also consider alternative theories for molecular evolution and explore the origin of life on earth. They study local ecosystems and interactions among populations to discover how living things change the environment as they interact with it.

The culminating unit of *Change over Time* considers the role of humans as they gained control over increasing amounts of energy as hunters, agriculturists, and industrialists. The course concludes in a series of simulation games in which students as decision makers balance knowledge and technical capacity with problems of overpopulation, resource depletion, energy consumption, and other forms of environmental stress.

General Structure of the *FAST* Program



HUMANS IN THE ENVIRONMENT
FAST 3
MECHANICAL ENERGY
ORGANIC CHEMISTRY
INTERDISCIPLINARY CONCEPTS
TIME AND CHANGE; EARTH, UNIVERSE, ORGANISMS, ECOSYSTEMS
PRODUCTIVITY IN ECOSYSTEMS/ WORLD FOOD PRODUCTION
FAST 2
ENERGY, ATOMIC THEORY, KINETIC MOLECULAR THEORY
INTERDISCIPLINARY CONCEPTS
ENERGY FLOW & CYCLING OF MATTER IN THE BIOSPHERE
AIR POLLUTION/ WATER RESOURCE MANAGEMENT
FAST 1
MATTER, TEMPERATURE, & HEAT
INTERDISCIPLINARY CONCEPTS
PLANTS, ANIMALS, & THE LOCAL ENVIRONMENT
ELEMENTARY BASE
KEY:
PHYSICAL SCIENCE
ECOLOGY
RELATIONAL STUDY

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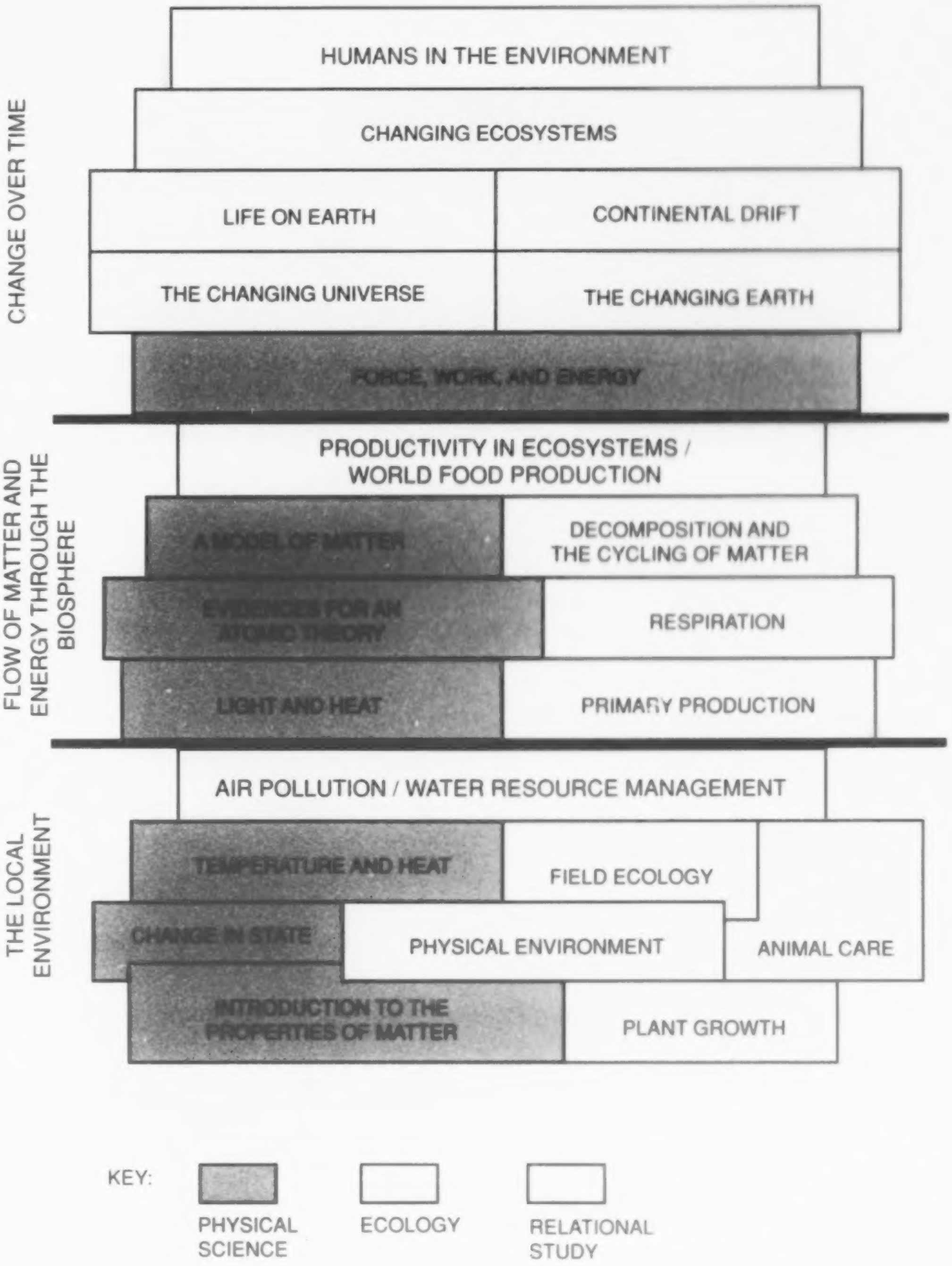
FAST Unit Diagram


CHANGE OVER TIME
HUMANS IN THE ENVIRONMENT
CHANGING ECOSYSTEMS
LIFE ON EARTH
CONTINENTAL DRIFT
THE CHANGING UNIVERSE
THE CHANGING EARTH
FORCE, WORK, AND ENERGY
FLOW OF MATTER AND ENERGY THROUGH THE BIOSPHERE
PRODUCTIVITY IN ECOSYSTEMS / WORLD FOOD PRODUCTION
A MODEL OF MATTER
DECOMPOSITION AND THE CYCLING OF MATTER
EVIDENCES FOR AN ATOMIC THEORY
RESPIRATION
LIGHT AND HEAT
PRIMARY PRODUCTION
THE LOCAL ENVIRONMENT
AIR POLLUTION / WATER RESOURCE MANAGEMENT
TEMPERATURE AND HEAT
FIELD ECOLOGY
CHANGE IN STATE
PHYSICAL ENVIRONMENT
ANIMAL CARE
INTRODUCTION TO THE PROPERTIES OF MATTER
PLANT GROWTH
KEY:
PHYSICAL SCIENCE
ECOLOGY
RELATIONAL STUDY

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CONCEPTUAL FRAMEWORK OF *THE LOCAL ENVIRONMENT*

The unifying theme of *FAST 1* is the local environment. To gain understanding of their own environment, students conduct laboratory and field investigations to identify its components—plants, animals, and physical factors— focusing on interrelationships among them. They do laboratory activities to find explanations of the physical factors.

Work in the laboratory and field capitalizes on the excitement of discovery and engages students in activities characteristic of a modern scientific community. Investigation requires careful attention to planning, executing, and interpreting experiments and community validation of results.

In the Physical Science strand, students first investigate basic concepts of science, including mass, volume, and density, as well as the relationships between density and buoyancy. In so doing, they work with all three states of matter—solids, liquids, and gases—and use their knowledge to explain everyday phenomena. By the end of the first unit, they can define matter as having mass and volume and the derived property of density, and they know that matter exists in three states. It is here that students also begin to learn basic laboratory skills.

Next they investigate the melting, freezing, boiling, and condensing of pure substances and mixtures and use their knowledge of change of state to identify unknown substances. They also conduct experiments on fluid mechanics—the capacity of gases and liquids to transmit pressure and to be compressed or attenuated. They measure vapor pressure using student-made manometers and refine their definitions of *change of state* by considering the effects of pressure.

Throughout their investigations of buoyancy and density and change of state, students find that some form of heat or energy is involved in change. Investigations in the final Physical Science unit focus on energy relationships. Students invent heat-measuring devices and derive the calorie as a standard unit of heat measurement. All these physical science concepts are applied in study of the environment.

Concurrently, in the Ecology strand, students investigate plants, animals, and the physical environment, in the laboratory and in an outdoor class study area. In the Plant Growth unit they develop an understanding of experimental design in investigating the effects of scarification on the germination of seeds with hard coats. They then design their own experiments to investigate environmental effects on plant propagation. The units emphasize experimental design and communicating findings orally and in writing.

In the Animal Care unit, students raise an animal from the class study area through one life cycle. They learn about life needs, behaviors, habitats, and niches, as well as interactions with other organisms. They study the interactions and movements of water through the soil, air, and plants in the Physical Environment unit. They build their own instruments for analyzing soil-water interactions, collecting weather data, collecting and measuring raindrops, and measuring transpiration. In the final activity of the unit, they trace the water cycle from their investigations.

The Field Ecology unit is designed to unite all of the Ecology strand into a whole. It focuses on the interactions and interdependence among plants, animals, and the physical environment in the class study area. Students build field-mapping instruments and make a detailed scale map of their study area. They also conduct quadrat studies of environmental change over time and learn how to estimate population sizes by using sampling techniques. In the last investigation, they conduct their own research of an ecological problem within the study area.

Through the Relational Study strand, students focus on the interrelationships of their studies in Physical Science and Ecology. For instance, their knowledge of buoyancy is applied to explaining floating and sinking objects in the environment, the floating of clouds, and the working of their soil analysis apparatus. Similarly, their knowledge of change of state and specific heats enables students to explain weather phenomena, ocean and air currents, air pressure, and the movement of water in the hydrologic cycle.

In addition, the Relational Study strand contains two units that call for students to draw on what they have learned in both Physical Science and Ecology during the year and apply their knowledge and skills to the study of a community environmental issue—either air pollution or water resource management.

One of the major objectives of *FAST* is to develop skills in measurement and in laboratory practice. Students learn to manipulate standard laboratory equipment such as metersticks, balances, glassware, graduated cylinders, thermometers, overflow cups, and heating devices. They learn and practice safe laboratory procedures.

FAST also emphasizes research skills such as planning, designing, and executing valid experiments, collecting and organizing data, constructing and using graphs, and communicating results. *FAST* investigations develop thinking and problem-solving skills as well as manipulative skills.

In addition to science skills, *FAST* fosters and enhances interpersonal skills. Most work is done in small collaborative groups where students share leadership as they share data, ideas, and inventions. The ability to get along with others, cooperate, and get a job done is cultivated through example and practice. All these skills are considered foundational for general education and scientific endeavor.

SCHEDULE AND SEQUENCE OF UNITS

The Ecology and Physical Science strands of *FAST* are presented concurrently by alternating short sequences of investigations from each strand. Ecology units overlap, one unit often beginning before previous units are completed. This is especially true of investigations that depend on the weather. Such investigations should be started even though previous units may not be finished. See the schedule on page xvi.

The concurrent and alternating presentation of the Physical Science and Ecology strands provides frequent changes of pace. Alternating between strands gives students time to reflect on observations, to see the application of observations in a different setting, and to avoid getting bogged down in the details of investigations. Alternating allows time for long-term data collection required by many Ecology investigations.

FAST 1 as a Two-Year Program

FAST 1, The Local Environment, has been adapted by many school systems as a two-year science program. Because the course is designed to contain more investigations than can be completed in one year, it lends itself well to such adaptation. The extended use of *FAST 1* over two grade levels ensures that students more completely grasp the foundational skills and concepts that are the essence of *FAST*.

A suggested schedule for using *FAST 1* as a two-year program appears on pages xvii and xviii. Investigations in Physical Science are again approached sequentially, beginning with Investigation 1, Liquids and Vials. In Ecology, the study of animals is suggested each year. In the first year, students should care for small animals such as mice, rabbits, quail, guinea pigs, and gerbils. In the second year they should focus on insects and similar organisms suggested in the Animal Care unit. This plan gives them experience in handling and caring for small mammals and birds before they do more sophisticated animal investigations. To maintain the structure and philosophy of *FAST*, one Relational Study unit should be done each year.

Suggested Schedule for Using *FAST 1* as a One-Year Science Program

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	**Unit 1** **Introduction to the Properties of Matter**	Seed Germination				
Oct.		Plant Propagation	Soil and Water		Field Survey	
Nov.			Water in the Air			
Dec.	**Unit 2** **Changes of State in Matter**					
Jan.			Weather Station		Field Sampling	
Feb.				Animal Care		
Mar.	Unit 3 Temperature and Heat		Rain			Air Pollution or Water Resource Management
Apr.			Water out of Plants		Field Ecology	
May						
June						

Suggested Schedule for Using *FAST 1* as a Two-Year Science Program: Year 1

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	**Unit 1** **Investigations 1 to 12**	Seed Germination			Initial Field Survey	
Oct.			Soil and Water			
Nov.						
Dec.			Water in the Air			
Jan.	**Investigations 13 & 14**		Weather Station		Repeat Quadrats	
Feb.	**Investigations 15 to 17**			Animal Care		
Mar.		Plant Propagation				Water Resource Management
Apr.			Rain			
May			Water out of Plants		Repeat Quadrats	
June						

101

Suggested Schedule for Using *FAST 1* as a Two-Year Science Program: Year 2

MONTH	PHYSICAL SCIENCE	ECOLOGY				RELATIONAL STUDY
		Unit 1 Plant Growth	Unit 2 Physical Environment	Unit 3 Animal Care	Unit 4 Field Ecology	
Sept.	Unit 2 Changes of State in Matter				Field Survey	
Oct.				Animal Care		
Nov.					Field Sampling (add soil tests)	
Dec.						
Jan.						Weather Stations
Feb.	Unit 3 Temperature and Heat					Air Pollution Measurement
Mar.					Field Resurvey	
Apr.					Field Ecology	Air Pollution
May						
June						

FAST INSTRUCTIONAL MATERIALS

A variety of student and teacher materials is available to guide and support *FAST* investigations.

Student Materials

Student book
Student record book
Reference booklets

Teacher Materials

Teacher's guide
Instructional guide
Evaluation guide
Data management software
Visual aid masters

Student Book
FAST student books contain background information, problem statements, procedures to guide investigations, and summary questions that focus on generalizations to be drawn from each activity. As students progress through the course, they write their own and the class's observations, data, hypotheses, and conclusions in their notebooks. Their running logs of investigations become their own textbooks. The student book is a guide to the sequencing of investigations. Its Appendix provides information on the metric measurement system and describes instruments and units for measuring linear distance, mass, area, volume, temperature, and time.

Student Record Book
The student record book contains both data tables and space for recording notes and observations of investigations presented in the student book. The record book enables students to maintain a concise log of individual and class activities. It fits in a three-ring binder along with the student's own notes.

Reference Booklets
To support investigations, a classroom library of reference booklets is provided. These booklets describe the use of instruments, suggest experimental designs, outline experimental techniques, and provide supplemental information as needed. The booklets give students practice in using outside references to supplement the information they derive from their own investigations. The following reference booklets are available for *FAST 1:*

"Air Pollution"
Discussion of means of measuring pollution, assessing its effects, and controlling it in any environment, with an examination of technologies for pollution control and an annotated list of federal laws pertaining to pollution.

"Animal Care"
Instructions for building cages and environments for keeping animals often found on schoolgrounds, with basic information on the food and habitat needs of 35 kinds of animals.

"Field Mapping"
Instructions for making detailed, scaled, and contour-lined maps of a class study area and for making and using mapping tools such as a stringed meterstick, a sighter, a range pole, and a meter level.

"Plant Propagation"
Propagating and growing plants from bulbs, cuttings, seeds, seedlings, and underground parts, with techniques for grafting, air layering, and using hydroponic solutions; investigations of each method; discussion of dormancy, planting containers and media, and watering.

"Sampling Methods"
Techniques for determining population size, density, and frequency by random sampling and by using quadrats, transects, and other methods.

"Weather Instruments"
Instructions for building a weather station, for making weather instruments including a rain gauge, a hygrometer, a wind vane, and an anemometer, and for setting up instruments to measure air quality.

Teacher's Guide

The logic connecting investigations and strands is explained in the teacher's guide. The guide, which is keyed to the investigations in the student book, contains teaching suggestions, advice on classroom procedures, and detailed discussion of the conceptual and practical progression of the student investigations. It also includes lists of equipment and chemicals, suggested schedules, and other information for using the program.

Instructional Guide

The instructional guide explains the philosophy, objectives, and design of the *FAST* program. It describes *FAST* components and suggests schedules, sequences, and strategies for organizing and managing the class.

Evaluation Guide

The evaluation guide describes the kinds of student evaluations built into the *FAST* program and tells how to use them to help students achieve their potential. It includes tests for assessing laboratory skills and understanding of concepts. The evaluations are also a means of involving students in self-evaluation. The guide contains a series of class progress records and an inventory of skills and concepts for use as individual progress records. These progress records are designed to help students and teachers know which concepts and skills have been mastered and which ones should be further developed to meet the expectations of the program. Software for Macintosh or Apple IIe computers is available to complement the evaluation guide. This software eases monitoring of student performance on *FAST* evaluations and provides printouts of class progress records and student progress records.

Data Management Software

Software specific to investigations in *FAST 1* is available for Macintosh and Apple IIe computers. The software enables students or teachers to enter experimental data; the computer displays data tables and a graphic analysis of the class data. Printout options include data tables, graphs of plotted data, and graphs of plotted data with line of best fit.

Visual Aid Masters

A packet of visual aid masters accompanies the teacher's guide. It contains reproducible materials to be used as transparency masters or optional student pages.

INSTRUCTIONAL MATERIALS FORMAT

With occasional exceptions, this format is used for investigations in the student book.

Format of Student Book

INVESTIGATION NUMBER AND TITLE

Background

Introduces the investigation and reviews earlier related investigations.

Problem or Activity

States a question to be answered or an activity to be done.

Materials

Lists the equipment and supplies needed for an investigation.

Procedure

Gives instructions for doing an investigation.

Summary

Asks questions to guide analysis and interpretation of results of the investigation.

Challenge

Suggests further investigations.
Sometimes leads into the next investigation.

Format of Teacher's Guide

Each strand in *FAST* is organized by units. Most units have two or more sections, each a sequence of investigations to be done by students.

UNIT

UNIT NUMBER AND TITLE

RATIONALE

Describes reasons for including the unit in the course.
Relates unit to other units.
States objectives of the unit.

OVERVIEW

Describes content and activities of the unit.
Relates sections of the unit to one another.

STRATEGY

Suggests ways to introduce and teach the unit.
Specifies required weather considerations and other information.

SECTION

SECTION TITLE

RATIONALE

Details goals and objectives of the section.
Relates section to other sections.

OVERVIEW

Describes content and activities in the section.

STRATEGY

Suggests ways to introduce and teach the section.
Details some useful techniques.
Specifies weather requirements, if any.

SUGGESTED SCHEDULE

Recommends sequence and time allotments for each investigation.

Investigations

Each investigation, whatever its length, begins with a digest designed as a one-page lesson plan. After the digest comes a description of the rationale and objectives of the investigation, then an overview of the student activities with a list of needed materials. Notes for the teacher follow, organized under the same headings as in the digest: review, introduction of new work, student activities, summary, and challenge. These notes provide detailed suggestions for organizing and teaching each investigation.

DIGEST

REVIEW

General statements reviewing pertinent ideas developed previously

VOCABULARY

A list of new words introduced in the investigation.

INTRODUCTION OF NEW WORK

Suggested approaches to the new topic

Single boxes indicate teacher responsibilities.

STUDENT ACTIVITY

Problem: Statement of the problem or activity (from the student book)

Flow diagrams of procedures and apparatus

Procedures for doing the investigation

Double boxes indicate student responsibilities.

SUMMARY

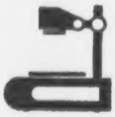
Summary questions about data analysis and generalizations deriving from the investigation

CHALLENGE

Challenge questions (from the student book)

Graphics Used in the Teacher's Guide

Graphics in the left margin of the teacher's guide identify special information.



The projector logo indicates that a transparency master or optional student page is provided in the packet of Visual Aid Masters accompanying the guide. A transparency master may be a class data sheet or a diagram of instructions.

Optional student pages usually contain too much information to make good transparencies. They may be duplicated for distribution to students.

FAST 1 SAFETY ADVISORY

No hands-on program can be 100% hazard-free. The *FAST* program has been carefully designed to give students hands-on experiences in the sciences in a safe environment. However, there is no guarantee, expressed or implied, that an experiment or procedure will not result in injury. New information about the health and safety hazards of substances is constantly coming to light.

Science teachers should take steps to provide safe laboratory and field experiences for students and themselves while minimizing health and safety risks. Science teachers should complete
- a science safety course,
- a first aid course, and
- a CPR course.

Check with your school safety officer for regulations and procedures in your area. Fire and building codes and regulations for laboratory procedures and for use, storage, and disposal of chemicals vary by state and locality.

References on school science safety are listed at the end of this advisory. Each science teacher should have these safety references available. Ask to be placed on mailing lists for updates on health and safety information.

GENERAL SAFETY AND WORK HABITS

- Never allow students to work alone in the laboratory.
- Never allow eating or drinking in the laboratory or storage area.
- Wash hands after working in the laboratory.
- Restrain loose clothing and long hair. Do not wear jewelry in the laboratory.
- Require everyone to wear approved eye protection. Prescription glasses and contact lenses are not safe.
- Require everyone to wear laboratory coats or aprons to protect skin and clothing.
- Require footwear that covers feet completely; open-toe shoes are not safe.
- Never leave heat sources unattended.
- Anticipate accidents and hazards and take steps to avert them.
- When accidents occur, analyze the mistakes with the class to prevent repeats.
- Conduct regular in-house safety and health inspections, with stress on improvement.
- Carry out regular fire and emergency drills, with critical reviews of the results.
- Plan actions to take in emergencies (which devices to turn off, how to turn them off, which escape route to take, where to meet outside, and so on).
- If chemicals splash on skin or clothing, rinse immediately with great quantities of water to dilute and wash away the chemicals.
- Always use heat-resistant glassware. Look for heat-resistant labeling on glassware. Do not use household items as substitutes in heating activities.
- Inspect all glassware for cracks. Have a designated container for disposing of broken glassware.

- Instruct students in proper ways to insert thermometers and glass tubing into rubber stoppers. Practice inserting glass tubing safely. (One way is to insert a cork borer into the hole in the stopper, slide the glass tubing or thermometer through the borer, and then remove the borer.)
- Check and approve all student-designed experiments before they are performed.
- Arrange for school personnel to supervise all field excursions. Inspect each site for possible hazards prior to the excursion.

FACILITIES AND EQUIPMENT

- Be sure the room is not overcrowded.
- Make sure science classrooms are well ventilated. If they are not, do not attempt lab activities requiring ventilation.
- Make sure fume hoods, if available, are properly maintained. Do not use fume hoods for storage.
- Install chemical storage shelves with lips to prevent containers from falling.
- Have separate containers for trash and broken glass.
- Keep all escape routes clear and unobstructed. All rooms should have at least two escape routes.
- Provide eye-wash stations and instruct students in their proper use.
- Regularly maintain fire extinguishers and instruct students in their proper use.
- Regularly inspect fire blankets for rips and holes.
- If possible, purchase chemicals in class-size quantities only.
- Label all chemicals accurately, including the date of receipt.
- Follow all directions for disposing of residues and unused reagents.
- Store chemicals properly. An excellent source of recommendations for proper storage is Flinn Scientific, Inc. (See Safety References.)

The table below provides health and safety information on substances used in *FAST 1, The Local Environment.*

ITEM	COMMONLY USED IN	HEALTH ADVISORY	SAFETY ADVISORY	OTHER COMMENTS
Cobalt chloride	Humidity indicator devices	Toxic by ingestion; possible irritant to eyes, skin, and respiratory system		Wash hands after handling.
Dry ice	Refrigeration	Damaging to skin and eyes		Do not touch with bare hands.
Ethyl alcohol	Alcoholic beverages	Toxic by ingestion	Flammable	Store in flammables cabinet.
Glycerin	Skin lotion; used as sweetening agent and solvent in medicines	Some people are allergic to glycerin; it may irritate eyes or skin		
Hydrogen	Used as a fuel		Highly flammable; explosive	Allow no flame in classroom.
Magnesium sulfate	Epsom salts	Irritates eyes and respiratory tract		
Mercury	Thermometers	[Discontinued for student use in *FAST*. Substitute alcohol thermometers. Teacher demonstration using mercury in manometer requires closed system to contain vapors. Highly toxic by skin absorption and by inhalation of vapor. Continuous exposure to small concentrations is harmful. Mercury detectors and mercury-absorbing sponges to clean up spills are available from Flinn Scientific, Inc.]		
Methane	Swamp gas; city gas used in cooking and heating	Toxic by inhalation	Highly flammable; explosive	Allow no flame in classroom.
Methanol	Duplicating fluid	Toxic by ingestion	Flammable	Store in flammables cabinet.

ITEM	COMMONLY USED IN	HEALTH ADVISORY	SAFETY ADVISORY	OTHER COMMENTS
Naphthalene	Moth balls	Toxic by ingestion, inhalation, and skin contact	Moderate fire hazard	
Paradichlorobenzene	Moth balls	Toxic by ingestion; irritant to eyes, skin, and respiratory tract		Keep quantities to a minimum.
Propane	Camp stoves and lanterns	Toxic by inhalation	Highly flammable; explosive	Allow no flame in classroom.
Sodium hydroxide	Lye; Drano	Corrosive; skin burns possible; dangerous to eyes; wear gloves	Heat generated when added to water	Should be used only under direct supervision. Use no more concentrated than 6M solution. Wear apron and goggles.
Sulfur	Matches	Low toxicity; may irritate skin	Fine powder can be an explosion risk	
Sulfuric acid	Battery acid	Severely corrosive to eyes, skin, and other tissues	Considerable heat of dilution with water mixing with water may cause spattering	Always add acid to water when diluting, never the reverse. Buy and store only small quantities.

REFERENCES

Council of State Science Supervisors, School Science Laboratories: A Guide to Some Hazardous Substances. Washington, D.C., U.S. Consumer Product Safety Commission, 1984.

Flinn Scientific, Inc. Chemical Catalog/Reference Manual. Batavia, IL, 1991.

National Institute for Occupational Safety and Health. Manual of Safety and Health Hazards in the School Science Laboratory. Washington, D.C., U.S. Department of Health and Human Services, 1980.

RATIONALE, OVERVIEW, REFERENCES

RATIONALE

Americans are becoming increasingly aware of the need to deal with potential environmental crises. One of the most pressing issues confronting people in all states is the quality and quantity of our water resources.

For many Americans, the crisis of water quality is already at hand. Some lakes and rivers are contaminated with municipal, industrial, and agricultural wastes. Pollution is threatening to contaminate sources of surface water and groundwater. Farms, industries, and cities are finding it difficult to get the water they need.

On a brighter side, we have made great progress since the 1970s in cleaning up the most obvious pollution problems. Many rivers returned to health after sewage and wastewater treatment plants were built or upgraded. Governments have enacted laws to preserve and protect clean water. We are learning more sophisticated techniques to monitor pollution. We must continue these efforts.

The objectives of this unit are to

1. develop awareness of the importance of water and its effects on our lives.
2. develop understanding of the local water system.
3. identify water uses and their regulation as important and continuing environmental issues.
4. identify sources, kinds, and effects of water pollutants.
5. develop skills for coping with environmental issues, including researching information, objectively considering alternatives, and making rational, informed decisions.
6. develop awareness and understanding of the interactions of science, technology, and society in making decisions about the environment.
7. further develop communication skills and creative expression through oral and written reporting, graphic display, art, and music.

OVERVIEW

Water Resource Management is an alternative to Relational Study Unit, Air Pollution. Students should complete one of the two in *FAST 1.*

Water Resource Management focuses on the study of water quality and quantity in the local community and region. Students begin in Section A by reviewing the hydrologic cycle in their studies of the physical environment. They collect data on personal uses of water and calculate family consumption of water. They then identify the sources of their water and trace the distribution system to the school and home. Throughout this whole unit, students identify and research local, state, and regional issues related to water resources.

In Section B students conduct experiments on water quality at a local field site. They collect data on temperature, salinity, dissolved gases, suspended solids and turbidity, nutrients, pH, and bacteria content. They then draw on their knowledge and skills developed in earlier investigations to design ways to purify water that has become contaminated. Concurrently with their experiments, they investigate how the local community treats wastewater. In the last investigation of Section B, they review state and federal laws on water quality and identify people responsible for managing and regulating water use in their community

Section C concludes the unit with a simulation in which students role-play community members deciding the fate of their last remaining wetland. The simulation demonstrates the interface of science, technology, and society by showing how decisions must balance scientific, political, economic, social, aesthetic, and environmental concerns.

REFERENCES

Water resource management is a continuing issue. New data, concerns, and regulations will continually emerge. It is impossible to provide current information for each state or region in a teacher's guide. The local newspaper is the best source of information on community water issues. See the suggestions for assembling and keeping a newspaper file in the introduction to Relational Study Unit, Air Pollution.

Besides your own state agencies that manage water and regulate its use, the following sources can provide current information on issues of managing the water resource:

- U.S. Environmental Protection Agency
  401 M St. S.W.
  Washington, D.C. 20460

The EPA has regional offices in Boston, New York City, Philadelphia, Atlanta, Chicago, Dallas, Kansas City, Denver, San Francisco, and Seattle.

- Fish and Wildlife Service
  Department of the Interior
  Washington, D.C. 20240

- Office of Environmental Education
  Department of Education
  400 Maryland Ave. S.W., Room 2025
  Washington, D.C. 20202

- Office of Coastal Zone Management
  National Oceanic and Atmospheric
  Administration
  Department of Commerce
  330 Whitehaven St. N.W.
  Washington, D.C. 20235

- Soil Conservation Service
  Department of Agriculture
  Washington, D.C. 20250

- U.S. Army Corps of Engineers
  Department of the Army
  Office of the Chief of Engineers
  Washington, D.C. 20314

- U.S. Water Resources Council
  2120 L St. N.W., Suite 800
  Washington, D.C. 20037

SECTION A. WATER IN MY COMMUNITY

RATIONALE

The problem of water quantity and availability is difficult for many people to comprehend. Three-fifths of Earth's surface is covered by water. Water is nature's most abundant natural resource. But only a fraction of the total water supply is available for human use.

The world's supply of water is contained within the hydrologic cycle. About 97% of it is salt water unavailable for direct consumption. An additional 2% is held in ice caps and glaciers. Only 0.6% of Earth's water is in underground reserves, only 0.3% in the atmosphere.

Although the amount of water within the hydrologic cycle is fixed, it is not distributed evenly throughout the world. The disparity is caused by regional differences in geography, climate, and atmospheric conditions such as wind and temperature.

Section A, Water in My Community, focuses on the hydrologic cycle and the water available for the community to use. Its objectives are to

1. review basic processes in the water cycle, including evaporation, condensation, precipitation, and transpiration.
2. develop awareness of personal uses of water and amounts of water consumed.
3. identify sources of the community water supply.
4. develop understanding of and appreciation for the technology of the water delivery system.
5. identify local issues related to water resource management.
6. further develop research and communication skills.

OVERVIEW

Students review their investigations of changes in state of matter in Physical Science and the flow of water through the environment in Ecology to identify processes in the hydrologic cycle. They collect data on personal uses of water and compare the amounts they use. They then identify sources of water in their community and prepare a water source map. They try to trace the system that distributes potable water from its source to their school and homes.

In the final investigation, students research recent and current water resource issues affecting their community. They prepare distribution maps for annual rainfall, housing, agricultural land use, and industrial use for their community and discuss how these factors contribute to community water issues.

SUGGESTED SCHEDULE

Investigation	Title	Approximate Number of Class Periods
1	The Water Cycle	1
2	Uses of Water	2
3	Distribution of Water	2–3
4	Local Issues	2+

1. THE WATER CYCLE

DIGEST

REVIEW

Review investigations in Physical Science and Ecology. Focus on what is known about the properties of water and its interactions in the environment.

VOCABULARY

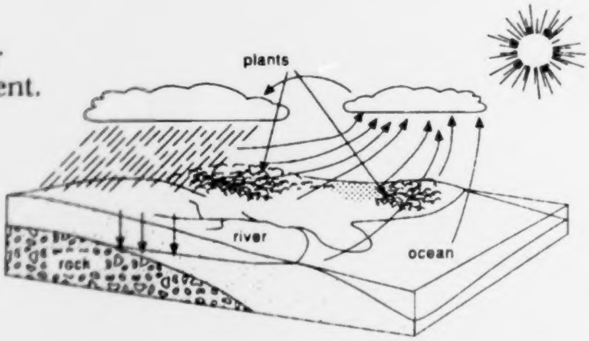
fossil water
hydrologic cycle
water cycle

INTRODUCTION OF NEW WORK

Define the hydrologic cycle as the flow of water through the environment.

STUDENT ACTIVITIES

Activity: Trace the flow of water through the environment.



A. Review Physical Science and Ecology investigations.
B. Trace the hydrologic cycle.
C. Play the Water Game to review the hydrologic cycle.
D. Create a representation of the hydrologic cycle.

SUMMARY (Questions 1, 2)

Share class projects on the hydrologic cycle.
The sun is the energy source for the hydrologic cycle.

CHALLENGE

A. How could water in the hydrologic cycle become polluted?
B. What other cycles in nature can you identify?
C. What is fossil water?

RATIONALE

Knowledge of the hydrologic cycle is essential to understanding and coping with water resource management issues. The objectives of this investigation are to

1. review previous investigations to identify interactions and changes of state in the hydrologic cycle.

2. trace and identify the processes in the hydrologic cycle.

3. further develop students' creative and communication skills.

OVERVIEW

Students review previous work related to water and trace the hydrologic cycle on a diagram from the student book. They play a question-and-answer game on facts related to the hydrologic cycle to develop and reinforce understanding. Finally, they design and carry out a project to demonstrate their understanding of the hydrologic cycle and present their projects to the class.

MATERIALS

- Water Game board and question cards (in Visual Aid Masters)
- dice, one die per group
- colored markers
- materials for student-designed projects

NOTES

REVIEW

Review the year's investigations of water. Physical Science Investigations 1–14 and 18–21 and Ecology Investigations 6–14 and 17–25 dealt with processes and interactions in the water cycle.

In Ecology Investigation 22, Water under the Ground, students had the opportunity to identify and trace the water cycle. If they completed that investigation, review it now in preparation for this activity.

INTRODUCTION OF NEW WORK

Introduce the term *hydrologic cycle*. Discuss the meaning of the word *cycle* and ask students to identify other cycles they know about. Develop a class definition of *cycle*.

Point out that *hydrologic* is a term used by earth scientists to describe the water cycle. Note that in this investigation students will review and further develop their knowledge of the water (or hydrologic) cycle.

STUDENT ACTIVITIES

Students can trace the diagram in their student book or use the one provided in the student record book. Or you may duplicate the page in the Visual Aid Masters.

Have students trace and identify the components of the hydrologic cycle. They can use crayons or colored pencils to identify the processes in the cycle.

Have groups share their descriptions. Review and discuss the essential elements of the hydrologic cycle.

Masters for a simple question-and-answer Water Game are in the Visual Aid Masters. Make copies of the game board and question cards for each group. The game should take about 15 minutes to play. Its purpose is to reinforce concepts of the hydrologic cycle.

After students play the game, have each group choose one of the suggested projects on the hydrologic cycle to do. The most useful project for later investigations is creating a file of newspaper articles about water resource management. See the introduction to Relational Study Unit, Air Pollution, for suggestions on how to do it.

SUMMARY (Questions 1, 2)

Have students share their representation projects on the hydrologic cycle. Post the projects for later reference.

The question about the source of the energy that powers the water cycle may be difficult. We have not dealt directly with this question, but energy in the form of heat was introduced in Physical Science Unit 3, Temperature and Heat. Help students conclude that the sun is the energy source that drives the hydrologic cycle.

The challenge questions should be pursued. They relate to investigations later in the unit. Accept students' responses at this time. The questions are designed to start them thinking. They can refine their answers later.

2. USES OF WATER

DIGEST

REVIEW

A. The flow of water through the environment can be described as the hydrologic cycle.
B. Hydrology is the study of the movement and distribution of water.

VOCABULARY

concept map
conservation
hydrology

INTRODUCTION OF NEW WORK

Water is vital for drinking, cleaning, cooking, growing and processing crops, and disposing of wastes.

STUDENT ACTIVITIES

Problem: How much water do you use?

A. Create a concept map of water uses.
B. Collect data on uses of water and amounts used by the class.
C. Compare data on uses of water.

Type of Use	Average Amount of Water Used (gallons)		Number of Uses per Day	Estimated Total Water Used per Day (gallons)
	Normal	Conservative		
Showering	25	4		
Bathing	36	12		
Brushing teeth	10	0.5		
Shaving	20	1		
Dishwashing by hand	30	5		
Dishwashing automatic	16	7		
Washing hands	2	1		
Flushing toilet	6	4.5		
Washing clothes	60	27		
Watering lawn by hand	10/min			
Watering lawn automatic	500			
Washing car	150	50		
Cleaning sidewalks	10			
Cooking				
Drinking				

Number of people in my family ____

SUMMARY (Questions 4, 5)

Discuss how quantities of water can be increased and amounts used reduced.

CHALLENGE

A. What are some uses of water not common 50 years ago but common today? How has the amount used per person changed in 50 years?
B. Plan and carry out a water conservation project in your home, school, or community. Report on the results.

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RATIONALE

Water management issues ultimately come down to individual decisions about using and conserving water. This investigation is designed to

1. identify ways water is used in the community.
2. develop awareness of the importance of water and its effects on individual lives.
3. identify the increasing demand for potable water as a continuing water resource issue.
4. begin to build a personal commitment to water conservation.
5. begin to relate water use to water quality.

OVERVIEW

Concept mapping is introduced as a way to record and categorize uses of water in the community. After students generate a list of water uses, they collect data on personal and family uses of water and amounts used in one day. They graph their data and compare amounts consumed by members of the class. They extrapolate from their data to estimate the quantity of water consumed by the school over periods of time.

MATERIALS (per group)

- chart paper
- graph paper
- colored marking pens

NOTES

REVIEW

Briefly review the hydrologic cycle established in the last investigation. Have students note that the energy source for the hydrologic cycle is the sun. If not already done, introduce the term *hydrology* for the study of the movement and distribution of water on Earth. Earth scientists who study water are called *hydrologists.*

INTRODUCTION OF NEW WORK

Water is essential for life. Growing plants use large quantities of water. Animals and humans must have water to carry on their life processes. Industries need water to manufacture their products. Water is needed for cleaning and for disposing of wastes.

Begin a discussion on uses of water to set the stage for this investigation. Have students estimate how many gallons of water they use in a day.

STUDENT ACTIVITIES

In the first part of the investigation have each group use colored pens and chart paper to prepare a concept map of water uses. After about 10 minutes, have the groups post and share their ideas about water uses. Consolidate all the uses in one list. Try to invent categories of uses. Some common categories are residential, commercial, public, private, hotels, industrial, agricultural, religious, and governmental (federal, state, city, or town). Students may think of other ways to categorize the uses.

For the second part of this investigation you may wish to duplicate Table 2-1 in the Visual Aid Masters for students. The master can also be used to make an overhead transparency for comparing class data. Assign students to keep a record of their daily water use for one day. Students should think about and discuss how much water they use for brushing teeth, washing hands, and flushing toilets, both at home and at school. They should estimate quantities consumed in uses that cannot be directly measured.

The next day distribute graph paper to each group. Have them make bar graphs of their personal and family water uses by type. Have groups share their results and calculate class averages. Make a class graph of the average quantity of water used by type of use.

When the class graph is complete, have students extrapolate the amount of water used by the school in a day, week, month, and year. Graph these data and post the graphs.

SUMMARY (Questions 4, 5)

Discuss ways students could reduce the amount of water they consume daily. Ask what effect their decisions would have on them and on their families and friends.

Point out that the total amount of water available for use is limited. Discuss ideas to increase the amount available, such as finding new sources, transporting water from elsewhere, and using available water more efficiently. Consider such things as costs and environmental effects of using other reserves of water.

CHALLENGE

The challenge questions should be pursued if time allows. The first focuses on changes in types of use and quantities of water consumed in the past 50 years. Students can collect data by interviewing older people or checking with the local water management office.

The second challenge asks for a personal commitment to conserve water. It is desirable to have students undertake a variety of projects at home, at school, and in the community. Home projects are best done individually. School and community projects allow for group effort.

3. DISTRIBUTION OF WATER

DIGEST

REVIEW

Individuals and communities use water in many ways and in huge quantities.

INTRODUCTION OF NEW WORK

A. Communities need a steady supply of clean water.
B. Surface water and groundwater are the main sources.
C. Listen to the movement of water in *The Moldau.*

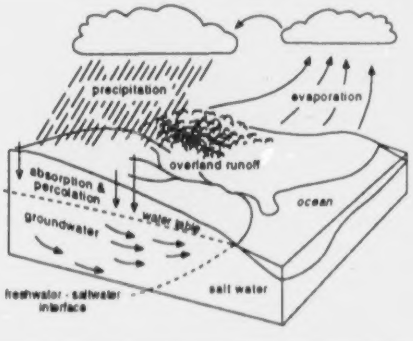
VOCABULARY

- aquifer
- bog
- delta
- estuary
- flood plain
- groundwater
- headwater
- marsh
- prairie pothole
- river system
- surface water
- swamp
- watershed
- water table

STUDENT ACTIVITIES

Problem: Where does our water come from?

A. Read the material about groundwater and surface water.
B. Use topographic maps to outline the community's watershed.
C. Identify water sources.
D. Trace the distribution system from its source to its point of use.


precipitation
evaporation
overland runoff
absorption & percolation
ocean
groundwater
water table
salt water
freshwater - saltwater interface

SUMMARY (Questions 1, 2, 4)

A. Post class map of the watershed.
B. Post drawings of distribution systems.
C. Discuss control and maintenance of the water distribution system.

CHALLENGE

A. Invite a water department engineer to speak to the class about the water distribution system in the community.
B. Find the meaning of *normal peak demand, per capita consumption, water pressure, pumping station, and gravity distribution.*
C. Make a model of the water distribution system of your school or home.

RATIONALE

Only about 0.6% of the world's water supply is available for direct consumption. It comes from two main sources, groundwater and surface water. Problems in moving water from its source to where it is needed have resulted in the creation of an impressive technology, that of the water distribution system.

The objectives of this investigation are to

1. distinguish between groundwater and surface water.
2. identify main types of surface waters as rivers, lakes, and wetlands.
3. develop an awareness of the importance of groundwater and surface water to the ecology of an area.
4. identify the watershed area for the community.
5. develop an understanding and appreciation of the technology of the water distribution system.

OVERVIEW

Students develop a sense of the aesthetics of water by listening to a musical representation of the sounds of moving water. They then read the background information in the student book. Drawing on their prior knowledge and their reading, they use topographic maps of the area surrounding the community to trace stream flow and identify their watershed. In the last part of the investigation they use indirect evidences and artifacts to draw the water distribution system from its source to the school and classroom.

MATERIALS

(per class)
- audiotape player
- audiotape of Smetana's *The Moldau*

(per group)
- topographic map of the area
- tracing paper
- drawing paper

NOTES

REVIEW

Review what students already know about water, including where it comes from and where it is stored in their community. Refer to Ecology Investigation 23, Water under the Ground, for general information on movement and storage of groundwater.

The question in this investigation is how water gets from its source to the sink in the home or school. When we turn on the water, few of us think about where it comes from or how it gets to us. But the movement of water from its source through the water distribution system to our faucets and fixtures is an engineering marvel. A quick review of the movement of water in the presence of pressures and vacuums in Physical Science Investigations 23 through 33 will be helpful.

INTRODUCTION OF NEW WORK

Moving water has fascinated, stimulated, and soothed human beings. Introduce this investigation by listening to a musical composition that represents the movement of water. Smetana's *The Moldau* is suggested, but you may want to substitute Respighi's *Fountains of Rome* or Handel's *Water Music.* These compositions have been recorded by a number of orchestras and are readily available on audiocassette.

Introduce the idea of music depicting scenes. Have students read the descriptions on the Visual Aid Master as they listen to the music. Have them try to visualize the scenes being described musically. You may want to play the piece a second time.

After the listening and reflecting, discuss the scenes with students. Ask them to try sketching the images the music aroused.

These are possible answers to the questions on the visual aid.

> The Source. A flute and a clarinet, two solo instruments, represent two springs. Eventually, the two instruments are sounded together, indicating the merger of the springs into a brook. A harp playing pizzicato represents droplets of spray.
>
> The River. More instruments and increasing volume suggest the brook growing into a river. Students may sing or hum the melody.
>
> The Hunt. The French horns imitate hunting horns—a good choice because the French horn originated in early hunting horns. The flow of the river continues through the hunt in the melodic and rhythmic figures played by the strings.

The Wedding. In almost every culture, a wedding calls for dancing. Smetana changes the rhythm of the music considerably to describe the regular bouncing beat of a dance.

Night on the River. The music changes again, becoming quieter as night falls on the river. It seems slower because the melody stretches into long notes, but the water still flows swiftly in the woodwinds. Fragments of Czechoslovakian marching songs recall the pageantry at ancient castles.

Rapids of St. John. Cymbals, kettledrums, piercing woodwinds, growling stringed basses, and brassy trumpets and trombones interact in dynamics and a faster tempo to recreate the rapids.

River Flows past Prague. The composer shows the river emerging from the rapids with a switch from minor to major mode in the main theme. Some students will be able to hear it. We are no longer passengers on the river, for despite the river's now immense size, the music becomes quieter as it flows out of sight toward the sea. The main river melody, repeated at three places in *The Moldau*, unifies the composition.

STUDENT ACTIVITIES

The background reading in the student book builds on Ecology Investigation 23, Water under the Ground, by adding information about groundwater and distinguishing it from surface water. The information about rivers and wetlands will be used later when students collect data on water quality at a field site and when they play roles in the culminating simulation of deciding the fate of a community marsh area.

Excellent videos to accompany this investigation are the Conserving America series produced by WQED/Pittsburgh and the National Wildlife Federation. Two videos in this series, *The Rivers* and *Wetlands*, support the reading.

Use topographic maps or highway maps if necessary for students to identify the water sources and watershed area for their region and to trace the applicable river system. Topographic maps are more useful than highway maps because they show more physical features of the terrain along with contour lines showing elevations. Refer students to the map key to identify symbols for water sources. Topographic maps of the region can be obtained from

Map Distribution Section
U.S. Geological Survey
Federal Center
Denver, CO 80225

Water Distribution System

Ask students if they have ever noticed the large holes covered with heavy metal plates in streets or sidewalks. These holes give access to water mains, gas mains, electrical systems, and other utilities. Each home and building has one water main or large water pipe that carries water from the original source to the home. Using maps and drawing on other information, have students trace the water distribution system for their community. Because much of the system is underground, they will have to look for indicators such as fire hydrants, water meters, sprinklers, fountains, and so on.

Inside buildings, the water distribution system remains mostly out of sight. Have students prepare a diagram of the water distribution system in the school. They will have to look under cupboards and in basements for water pipes and water heaters in addition to other indicators such as sinks, toilets, drinking fountains, and sprinkler systems.

If possible, invite a maintenance person from the staff of your water board to explain the water distribution system. Ask if they have blueprints. If they do, students can compare their drawings with the actual plans. Ask the guest to lead a field trip around the school to show students where water lines are.

SUMMARY (Questions 1, 2, 4)

Discuss the water distribution system in the community and the school. Note that supplying water reliably around the clock requires sophisticated technology that uses our knowledge of the properties of water, such as its ways of reacting to pressures and vacuums.

Find out who in your community is responsible for maintaining and controlling the delivery of water. Who pays these costs? How large a population can the system serve? What changes must be made in the system to prevent breakdown and to expand service to more users?

Discuss the effects that changes such as land development, clearing of watershed areas, increased demand for potable water, or prolonged drought could have on the water supply. Ask students to suggest ways to preserve and protect their water resources. Collect ideas and share them with the water board or the community newspaper. Help students begin to see that today's decisions about managing the water resource will affect the lives of their families.

The challenge questions offer an opportunity to extend this investigation by finding more information and connecting the community/school activity to students' homes.

4. LOCAL ISSUES

DIGEST

REVIEW

A. We have traced the hydrologic cycle and identified the water distribution system.
B. Water resources are limited.
C. Demand for clean water is increasing.

VOCABULARY

conflict
distribution map
issue
opinion

INTRODUCTION OF NEW WORK

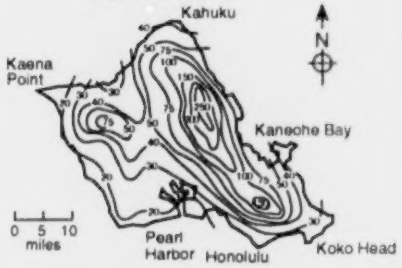
A. Managing the water resource is a continuing issue for all communities.
B. Discuss possible water problems in the local community.

STUDENT ACTIVITIES

Problem: 1. What are the local issues of water resource management?
2. How are these issues being resolved?

A. Collect newspaper articles about local water issues.
B. Prepare distribution maps for rainfall, agriculture, population, and industry.
C. Debate who should own/control the water in the community.

Annual Rainfall



SUMMARY (Questions 1, 2)

A. Compare distribution maps. Identify potential water problems.
B. Prepare and give a report on water resource management issues in the community.

CHALLENGE

A. Attend a hearing or community meeting on a water resource issue. Report your experience.
B. If you were going to build a new community, how would you select a place for it?
C. Find out what federal laws affect water quality in your community.

RATIONALE

Sooner or later every community must deal with problems of water resource management. Among the problems are contamination of water, an insufficient supply of clean water, and distribution of water from its source to the place it is needed.

The objectives of this investigation are to

1. identify community problems, conflicts, or issues related to water.
2. introduce news articles as a source of information.
3. develop critical thinking skill in analyzing newspaper reports.
4. further develop skill in distinguishing fact from opinion.

OVERVIEW

Students find, collect, and analyze newspaper articles about water resource issues in the community. By creating a class newspaper file, they build their awareness of problems and conflicts facing the community. They also collect data from library references and prepare distribution maps of rainfall, agriculture, population, and industry for the area. Using information from these sources, they predict emerging water issues. Finally, they debate the issue of control and use of local water resources.

MATERIALS

- newspaper articles
- class scrapbook for newspaper files
- chart paper
- colored pens
- regional atlas
- census data

NOTES

REVIEW

Review work done so far in the unit. Briefly review the hydrologic cycle and the community water distribution system. Point out that because the total available water on Earth is fixed, the water resource will always be limited. Contrast these limits with what students already know about the distribution of water on Earth and the rising demand for clean, potable water.

INTRODUCTION OF NEW WORK

Explain that students will continue their research into water problems in the community by reviewing and analyzing old and new newspaper articles to find information and to identify the opinions and judgments of writers and other key people. In this way they will discover whether there is a conflict and what solutions, if any, have been proposed for solving it.

Introduce the idea of distribution maps. Try to have maps from an atlas to show. Explain that students are to find out about the distribution of rainfall, population, agriculture, and industry in their community and make maps showing their distribution. Library work can be done in class or as homework.

STUDENT ACTIVITIES

Telling the librarians at school and community libraries about the assignment will let them get ready to help students find the information. Students will need time to find newspaper articles, older ones as well as current ones.

Have students individually or in groups write summaries of the articles they find. Help them distinguish fact from opinion in their readings. Where they find facts, they should look for supporting evidence. Where they find opinions, they should find out who is expressing them. Have them write summaries of the issues they identify. Keep the summaries with the articles in the class news file.

Distribution Maps

A large class map of the region can be made easily by tracing a map of the region on an overhead transparency, projecting the image onto a large paper, and tracing it. Areas of distribution of factors can be shaded with colored pens.

Have students analyze the distribution maps. You might ask questions like these:

- How has the demand for water in the community changed?
- What potential problems of water resource management do the maps suggest?
- How do these predictions fit with the data collected from newspaper articles?
- Who owns the water anyway?
- Who pays to use water? How much? Do all members of the community pay the same amount?

Class Debate
For the debate, divide the class in half. Decide which team will support the issue and which team will oppose it. Allow time for each group to prepare its arguments. Run the debate like a town meeting. Students may role-play elected officials, members of the local water board, or members of other decision-making groups. Some may also role-play a news team covering the event, possibly videotaping it for later playback and analysis.

SUMMARY

After the debate, debrief with the class. Help students differentiate factual arguments from emotional opinions. Note that such community debates over water issues will continue through their lifetimes because water is a vital resource in constant demand.

Assign individuals or groups of students to plan some ways to explain their understanding of the water issues facing the community. These can be shared with other classes, at a school open house, or with the community itself. Students may suggest other ways of expressing what they know. Note that this project is an assessment tool that allows both teachers and students to reflect on what they have learned in the investigations in this unit.

The challenge questions on finding out about federal laws that regulate water use and quality will be useful preparation for Investigation 7, Managing Water Resources.

SECTION B. MONITORING WATER QUALITY

RATIONALE

Water is vital, a necessity for all life. Yet we often show little regard for the quality of our water supply. When we use water, we rarely put it back into the hydrologic cycle as clean as it was before we used it. When our sewage or wastewater is not properly treated, it can kill fish, spread waterborne diseases, cause overgrowth of algae, and create the foul odor caused by a lack of free oxygen.

Agriculture uses a large share of the available water. Widespread use of fertilizers and pesticides on fields pollutes our water sources. Barnyard and feedlot wastes contaminate our lakes and streams. Runoff from improper farming practices adds a heavy load of silt to our surface water supply.

Industry also uses large quantities of water. Industries often use water of lower quality for their purposes, but industrial wastes dumped into the water supply cause untold damage. Industrial wastes may include oil, chemicals, and radioactive materials. Warm water dumped into the water supply after being used to cool machines can create thermal pollution that kills plant and animal life.

The objectives of Section B, Monitoring Water Quality, are to

1. identify sources and kinds of pollutants commonly found in water.
2. describe the damaging effects of water pollution on health and life.
3. introduce techniques for measuring water quality.
4. collect data on the presence of water pollutants in the community.
5. identify and describe ways of purifying contaminated water.
6. review legislation regulating uses of water.
7. further develop skill in analyzing and extrapolating from data.

OVERVIEW

Section B, Managing Water Quality, consists of three investigations. In the first, Testing Water Quality, students visit a water study area to collect data on its physical features and on dissolved gases, nutrients, salinity, suspended solids, acidity, bacteria, and other living organisms. Taken together, these data reveal the quality of the water and demonstrate how water quality is monitored.

In Investigation 6, Purifying Water, students research wastewater treatment in the community. Drawing on knowledge and skills developed earlier, they design and test experiments to purify a contaminated sample of water.

In the last investigation, Managing Water Resources, they learn of historical approaches to water rights in the United States. They learn about agencies charged with responsibility for managing the water resource and about federal laws governing water use. The culminating activity asks them to develop a water-conservation code for the class.

SUGGESTED SCHEDULE

Investigation	Title	Approximate Number of Class Periods
5	Testing Water Quality	4–5
6	Purifying Water	2–3
7	Managing Water Resources	2–3

5. TESTING WATER QUALITY

DIGEST

REVIEW

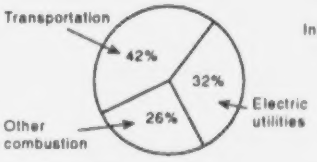
A. We each use a large quantity of water every day.
B. Agriculture and industry use large quantities of water.

INTRODUCTION OF NEW WORK

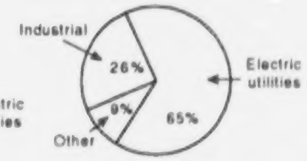
A. When we use water, we contaminate it.
B. Used water is called wastewater or sewage.

STUDENT ACTIVITIES

Problem: What evidence of water pollution, if any, can you find in your community?



Nitrogen emissions total 24.5 million tons/yr.



Sulfur dioxide emissions total 20.7 million tons/yr.

A. Prepare a Water Pollution Source Map.
B. Read instructions and prepare materials for testing water quality.
C. Conduct tests at a field site and in the classroom.

VOCABULARY

acid rain
aeration
algae
algae bloom
bacteria
brackish water
brine
dissolved gases
eutrophic
feces
hydrometer
nitrates
nonpathogenic
nonpoint source
nutrients
oligotrophic
pathogenic
pH
phosphates
plankton
point source
salinity
saturation value
sewage
source map
suspended solids
turbidity
wastewater

SUMMARY (Questions 1, 2, 3)

A. Teams report data collected on water quality.
B. Summarize findings from field site; post with Water Pollution Source Map.
C. Share findings with community members.

CHALLENGE

A. How can a hydrometer be used to measure the salinity of water?
B. Design an experiment to test the effects of acid rain or other pollutants on plants.

RATIONALE

The problem of water quality is grave nationwide. To ensure an ample water supply for the future, we must prevent and control pollution now. *Pollution* is the presence of substances in water in such quantities and of such quality that the water's value to other users is unreasonably impaired. This broad definition covers multiple uses of water, including personal, agricultural, and industrial.

The objectives of Investigation 5, Testing Water Quality, are to

1. introduce tests for pollutants in water.
2. distinguish between point and nonpoint sources of pollutants.
3. identify the primary water quality indicators as acidity, salinity, dissolved oxygen and carbon dioxide, nitrates and phosphates, suspended solids, algae, and bacteria.
4. further develop skill in collecting, interpreting, and summarizing field data.

OVERVIEW

Students refer to the map of the watershed area they prepared in Investigation 3, Distribution of Water, to identify and mark possible sources of pollution, distinguishing between point and nonpoint sources. This new map becomes the Water Pollution Source Map for the community.

The class divides into six teams, each team responsible for reading an assigned section in the student book on tests of water quality and preparation of test equipment. The class travels to a nearby water study area—a stream, lake, pond, or wetland—to collect and test water samples.

Back in class, the groups report what they have learned about water quality and what data they have collected. The data are summarized and analyzed to determine the overall quality of the water at the field site.

MATERIALS

Team A. Environment
- large sheet of map paper
- several stringed metersticks
- thermometer
- stopwatch
- 2 stakes
- weighted string
- long pole
- hammer
- ball, orange, or similiar floating object

Team B. Dissolved Substances
- pH indicator paper
- jars for water samples
- hydrometer
- watch

Team C. Dissolved Gases
- jars for water samples
- test kit for dissolved oxygen*
- 250-mL beaker
- 2 medicine droppers
- 50 mL phenolphthalein solution
- 50 mL sodium hydroxide solution
- graduated cylinder
- watch
- graph paper
- thermometer
- aprons and goggles

Team D. Nutrients
- jars for water samples
- test kit for nitrates*
- test kit for phosphates*
- aprons and goggles

Team E. Suspended Solids
- jars for water samples
- balance
- funnel
- filter paper
- flashlight

Team F. Living Organisms
- jars for water samples
- plankton tow net
- hand lens or microscope
- water-bacterial test kit*
- aprons and goggles

* Test kits are available from the following suppliers:

Test Kit for Dissolved Oxygen
Hach Chemical Corporation
P.O. Box 389
Loveland, CO 80539

Test Kit for Nitrates
Nitrate Test Kit
Hach Chemical Corporation
P.O. Box 389
Loveland, CO 80539

Test Kit for Phosphates
Phosphate Test Kit
LaMotte Chemical Corporation
P.O. Box 329
Chestertown, MD 21620

LaMotte Test Kit for Nitrates and Phosphates
LaMotte Chemical Corporation
P.O. Box 329
Chestertown, MD 21620
(available from many chemical supply companies)

Water-Bacterial Pollution Test Kit
Science Kit and Boreal Laboratories
P.O. Box 2726
Santa Fe Springs, CA 90670-4490

Preparing Solutions for Carbon Dioxide Test

Sodium hydroxide solution. Add 0.4 g sodium hydroxide to 1 L water. Mix well. Place in dropping bottles.

Phenolphthalein indicator. Buy prepared indicator solution or add .5 g phenolphthalein to 100 mL ethyl alcohol. Mix well. Place in dropping bottles.

NOTES

REVIEW

Briefly review information and issues uncovered in Section A, Water in My Community. Point out that every user of water changes its quality in some way. In this investigation, students will focus on ways to determine water quality.

INTRODUCTION OF NEW WORK

Natural and human activities pollute water. Some pollutants—organic matter from plants, animals, and soil—reach the water system naturally. Normally, these are easily tolerated and absorbed by the natural ecosystems. The natural purification process uses oxygen to decompose organic matter and break down pollutants. The time required to reach equilibrium is generally called the *recovery time.* But when an excess of organic matter enters the water, bacterial decomposition requires more oxygen than is available. The water's supply of oxygen is depleted, and organic matter begins to decay in an anaerobic process that produces hydrogen sulfide, a noxious gas.

Other wastes that pollute water come with rising population, more industrial and agricultural use, and disposal of complex wastes. Among the wastes dumped into our waters every day are phosphates and nitrates; pesticides and herbicides; bacteria and toxic wastes; oil, salts, and heavy metals; discharges of thermal (heated) water; and sewage and wastewater from cities, industries, and shipping.

Discuss possible sources of pollutants in the community's water supply. Distinguish between point and nonpoint sources.

STUDENT ACTIVITIES

Students may be able to revise their watershed map into a Water Pollution Source Map instead of making a new one, depending on how much data is already recorded on the watershed map.

Students can use their mapping skills to create a key for their map. For later discussions, it will be helpful to color-code point and nonpoint sources of pollutants.

Selecting a Water Study Area
A water study area may be any body of water near the school. A stream, a brook, a marsh, a pond, and a lake are good choices. Preview the area to document safety hazards, identify potential testing stations, and determine how many adults you will need to supervise students. (This may be a good opportunity for team teaching with teachers of other subject areas as well.)

Take special note of hazardous objects, deep or fast-moving water, and poisonous plants. Be sure students avoid these areas. Try to select testing stations accessible without disturbing the environment. Four to five testing stations should be enough for gathering reliable data.

Team Assignments
The team assignments are about equally difficult and take about the same amount of time to prepare for and complete at the field site. If the needed test kits are not available, have team members collect as much data as they can and then join another team.

The work is divided among class members to reduce the amount of information each student is responsible for and the amount of time taken in doing the investigation. It is important, however, for the teams to teach the rest of the class what they have learned. The teams' reports during the summary are essential. Remind students when they prepare their data that they will be teaching the class what they have learned about their assigned topics. You may refer them to Ecology Investigation 4, Oral Scientific Reports, for guidance on presenting their information and results. By this time, students should be able to present well-organized, informative, and concise oral reports.

A master of the Water Quality Report Form is in the Visual Aid Masters. It may be duplicated for students or used as an overhead transparency for organizing and summarizing team data.

If you want to extend this investigation, you could contact Delta Laboratories about the Adopt-a-Stream program, which invites people worried about the nation's waterways to act for their well-being. The program sponsors activities that schools and community groups can participate in. School projects are usually co-sponsored by a community group. Contact

Delta Laboratories, Inc.
32 Elton St.
Rochester, NY 14607

SUMMARY (Questions 1, 2, 3)

Let each team use the Water Quality Report Form to summarize the data from its testing station. Then consolidate the data into a final report on the quality of water in the study area.

Have team members explain to the class the information they were responsible for. Note particularly why these data are important to issues of water resource management. As each group reports, encourage the class to look for other interpretations and discuss implications for water quality at the site.

Help students interpret the data. Note that if tests show good quality, the community might want to know how to keep it high. If the quality is poor, ask students to suggest steps to improve it.

Findings from this investigation can be shared with the community through newspaper articles, letters to the editor, posters in public places, school bulletin boards, newsletters to parents, and other means. Encourage students to tell others what they found.

6. PURIFYING WATER

DIGEST

REVIEW

A. Water is recycled in the hydrologic cycle.
B. The average person uses about 150 gallons of water a day and produces about 120 gallons of wastewater.

INTRODUCTION OF NEW WORK

A. Wastewater can be purified for reuse.
B. The natural process of wastewater treatment is called *assimilation.*
C. Wastewater can also be cleaned in a sewage treatment plant.

VOCABULARY

assimilation
desalination
distillation
filtration
pollution
purify
septic tank
sewage treatment
solar still

STUDENT ACTIVITIES

Problem: 1. What happens to our wastewater?
2. How can contaminated water be purified so that it can be reused?

A. Find how sewage in your community is treated for reuse.
B. Design and carry out experiments to purify samples of contaminated water.

SUMMARY (Questions 1, 3, 4, 5)

A. Water can be purified by filtration, distillation, biological means, and chemical means.
B. Sewage treatment plants use primary, secondary, or tertiary treatment processes to clean water for reuse.

CHALLENGE

A. In some parts of the world seawater is desalinated to make fresh water. Find the cost of water in your community. Find the cost of desalinating water. Why is desalination not widely used to produce fresh water?
B. Arrange to visit a sewage treatment plant in your community. Identify the parts of the treatment system.
C. Invite a person from the agency responsible for sewage treatment in your community to speak to your class.
D. In what ways could you reduce the amount of sewage you produce each day? Make a plan to reduce your sewage by 10%. Try it out.

RATIONALE

Accumulations of waste strain our waterways. Much of the organic matter in wastewater can be assimilated by natural processes in streams, ponds, lakes, and other wetlands. But many communities produce more sewage than can be assimilated. Furthermore, some materials in wastewater are hard to remove. Concentrations of these materials find their way back into the hydrologic cycle and continue to pollute water sources.

Wastewater treatment plants concentrate natural processes to speed the breakdown of organic matter. As more sewage is produced, communities are forced to turn to more and more complex treatment methods to meet minimum standards for water reuse.

The objectives of Investigation 6, Purifying Water, are to

1. identify natural methods of purification, including evaporation, percolation, and aeration.
2. identify and describe the biological and chemical processes used in sewage treatment plants.
3. identify the volume of sewage produced by urban populations and the need for sewage treatment to recycle water.
4. describe desalination processes and their high cost.
5. further develop skill in designing and performing experiments.

OVERVIEW

Investigation 6, Purifying Water, has three important parts. The first comes in the background section of the student book, where students read how biological assimilation purifies water. This section also provides details on common water pollutants, their sources, and their effects.

In the second part of the investigation the class divides into teams, each of which researches and reports on an aspect of wastewater treatment. Teams identify and sketch the sewer system, including the treatment plant; they learn about primary, secondary, and tertiary sewage treatment; they find out how a septic tank purifies water. Teams share their findings in oral reports and visual representations.

In the third part they draw on their knowledge of changes of state and physical properties of matter, from Physical Science and Ecology investigations, to design and test methods of purifying samples of contaminated water. Typical methods include filtration and distillation.

MATERIALS

Laboratory equipment (per group)

- sample of contaminated water
- graph paper
- aprons and goggles
- other materials needed for experiments

Supply stations

- jars of various sizes
- heat source
- aluminum foil
- test tubes
- Erlenmeyer flasks
- stoppers
- clear plastic wrap
- glass tubing
- rubber tubing

Prepare contaminated water by mixing soil, coffee, nutmeg, powdered milk, or similar substances with water. Put samples in small jars, about 100 mL per sample, one jar per group. Make at least one sample of salt water—seawater if possible—to prepare the class for a discussion of desalination.

NOTES

REVIEW

Refer to the class graph of amounts of water used per person per day from Investigation 2, Uses of Water. Have students note that the average amount is quite large. Ask what happens to the used water. We know the water must be recycled in the hydrologic cycle, but how is it cleaned of wastes?

Most water used in homes and schools is for carrying wastes. Drinking, cooking, and even watering the lawn use less water than do cleaning, bathing, washing clothes, flushing toilets, and running the garbage disposer. Most wastewater is carried away in the sewer system running under the streets. Like the water distribution system, the sewer system cannot be observed directly. We must look for indirect evidence in artifacts such as fixtures, storm drains, access area covers, and so on.

INTRODUCTION OF NEW WORK

Introduce the investigation by showing a sample of contaminated water. Ask students if they would dare to drink the water. Point out that water can get contaminated by natural processes as well as by human activities. Ask how water might be purified in nature. List ideas on the board.

Introduce and discuss biological assimilation, explained in the student book. Also review the information in Table 6–1 on common water pollutants, their sources, and their known effects. Refer to earlier investigations in this unit. What evidence of pollutants, if any, have students seen in community water supplies?

Note that the investigation on purifying water requires library and laboratory research. First, teams of students are assigned topics to research in the community or the library. See Table 6–2 for team assignments. Then each team is given a sample of contaminated water and asked to design a way to purify it to make it reusable. The two parts can be done concurrently because the first requires out-of-school research and the second is done in the laboratory.

STUDENT ACTIVITIES

A public library or the local wastewater agency can supply information on the community sewage system. Information on primary, secondary, and tertiary sewage treatment is available in reference books at libraries. See the brief description below and diagrams in the Visual Aid Masters.

Primary Sewage Treatment

Sewage entering a plant for treatment flows through a screen that removes large objects that may clog pumps. Some treatment plants use a device called a *comminutor* that also grinds up large objects. After screening, the sewage passes into a grit chamber, where sand, grit, cinders, and small stones settle out. (This material is often used for landfill.) Then the sewage goes to a sedimentation tank, where finer particles settle out. See Figure T-6-1. Have students recall the settling experiments they did when they analyzed soils.

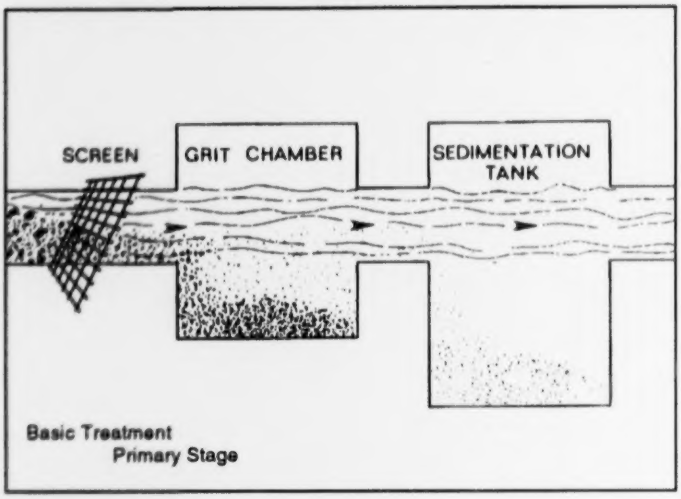


Figure T-6-1 Primary sewage treatment

Secondary Sewage Treatment

The secondary stage of treatment removes up to 90% of the organic matter in wastewater, allowing bacteria to decompose it into harmless substances. Organic matter is removed by using a trickling filter or an activated sludge process.

A trickling filter is a bed of stones 3 to 6 feet deep through which the sewage passes. Bacteria gathered on the stones consume most of the organic matter. Cleaner water trickles through the pipes in the bottom of the filter.

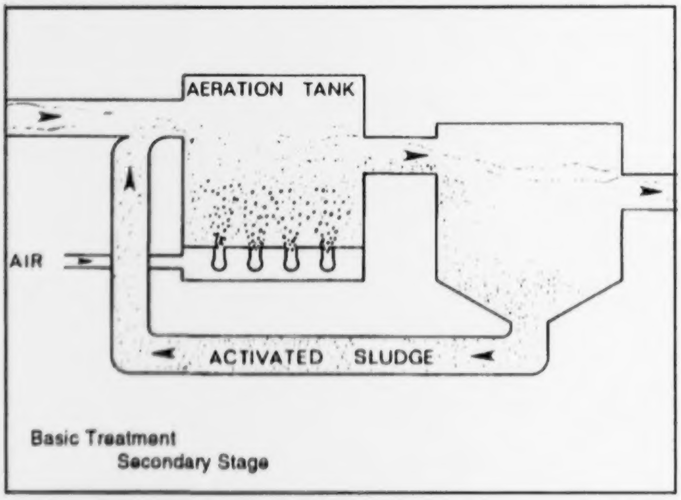


Figure T-6-2 Secondary sewage treatment

The activated sludge process is more commonly used today because it speeds decomposition by pumping air into the sewage. The extra air makes bacteria and other tiny organisms grow and reproduce rapidly, decomposing sewage faster. The activated sludge process takes less land space than the trickling filter, and it is free of flies and odors, but it costs more to operate.

Tertiary Sewage Treatment

Some cities give sewage tertiary treatment before releasing water back into the system. Tertiary treatment requires such sophisticated processes as the use of absorbents, chemical exchange, reverse osmosis, and ozone treatment. These processes remove chemicals that entered the water from pesticides, fertilizers, and industrial products. The treated water, called *effluent*, is released back into the water system.

Septic Tank

In rural areas without a community sewage treatment system, household sewage is treated in a septic tank buried in the ground. Wastewater flows from the home into the tank, where bacteria in the sewage break down organic matter. Cleaner water flows out of the tank into the ground through subsurface drains. The sludge in the bottom of the septic tank must be cleaned periodically.

Have students sketch their sewage treatment plant or make a model showing inflow, primary, secondary, and tertiary treatment, and the outflow of effluent. If possible, have them identify the system used in the plant that treats their sewage. Point out that sewage treatment plants use natural processes to clean the water but using technology speeds up the process.

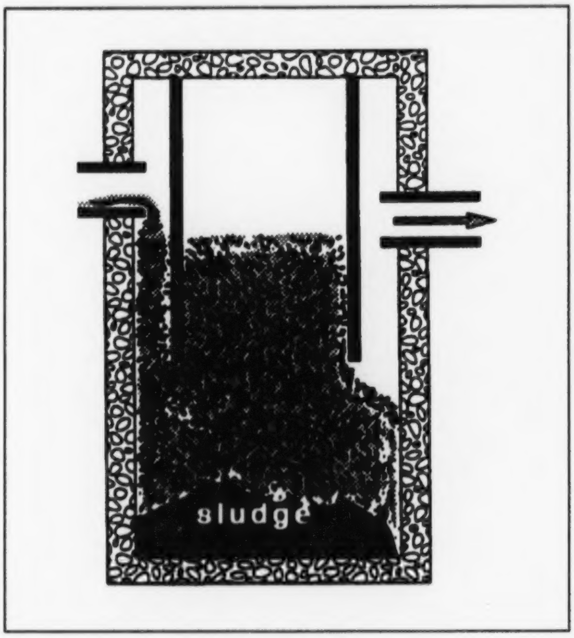


Figure T–6–3 Septic tank

Purifying a Contaminated Water Sample

Students' designs will vary but are likely to use evaporation, distillation, and/or filtration. Be sure to approve all experimental designs before students begin. Examples of some workable designs are shown below.

Filtration

Filtration purifies water by removing suspended particles as water flows through sand and gravel. Filtration imitates the natural method in streams and watershed areas. It is used in primary treatment plants.

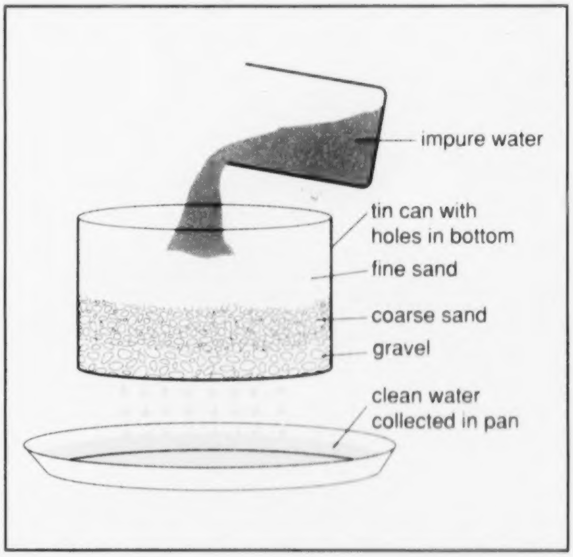


Figure T–6–4 Filtering contaminated water to remove solids

Distillation

Distillation purifies water through evaporation. Clean water is collected by condensing water vapor, leaving impurities behind in the heating chamber. There are many variations on the basic design shown in Figure T–6–5.

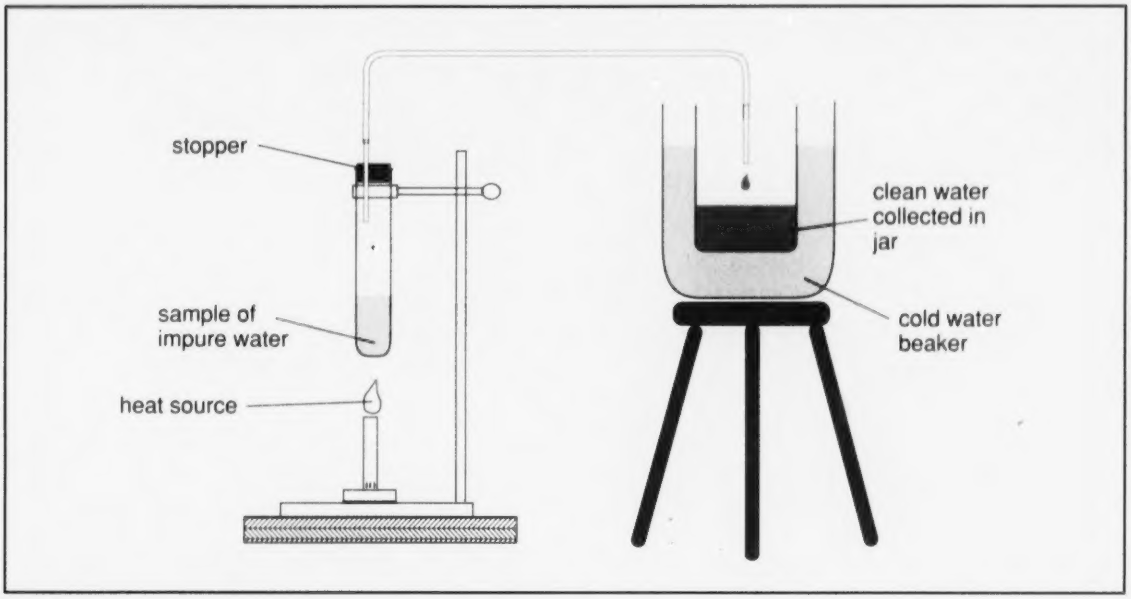

stopper
clean water collected in jar
sample of impure water
cold water beaker
heat source

Figure T–6–5 Distilling water to remove impurities

Solar Still

A solar still uses the sun's energy to evaporate water. A still is a common survival device in dry areas of the world. Cover a jar, can, or terrarium with clear plastic wrap and set a small stone on top to make a dent in it. Place the still in sunlight. Clean water evaporates from the impure sample, collects on the plastic, runs to the lowest point of the dent, and drips into a container. There are many variations of the basic design shown in Figure T–6–6.

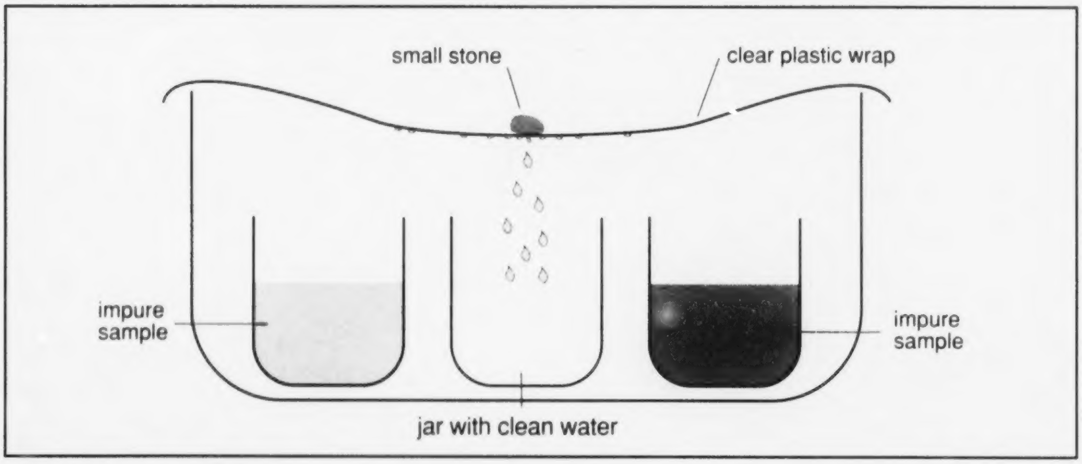

small stone
clear plastic wrap
impure sample
impure sample
jar with clean water

Figure T–6–6 A solar still

Desalination

Desalination is a distillation process. The energy and the machinery it uses make it an expensive method of producing fresh water. Figure T-6-7 shows a sample apparatus.

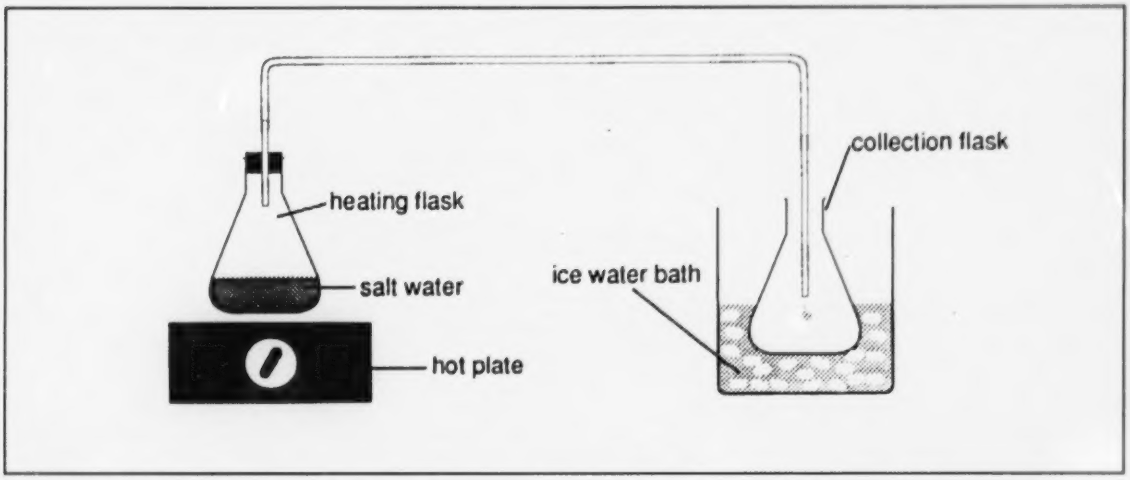


Figure T-6-7 Desalination by distillation

SUMMARY (Questions 1, 3, 4, 5)

Hold a seminar in which students share what they learned about sewage treatment in the community. Identify which level of sewage treatment is used. Probe by asking why other methods are not used. Have students summarize their findings in written reports. Also have students display and explain their water purification designs. Focus on how much water was lost in the process. Where did it go? Also discuss the meaning of *pure water*. Would students be willing to drink the water they purified with their devices?

NOTE: Do not let students taste or drink any of the samples.

Share information with other schools, states, or countries. Contact *FAST* headquarters for information about linking with *FAST* classes in other places via computer networking.

7. MANAGING WATER RESOURCES

DIGEST

REVIEW

A. We have reviewed the hydrologic cycle, learned how water is distributed and used in the community, and tested the quality of our water.
B. Who is responsible for ensuring water quality in the community?

INTRODUCTION OF NEW WORK

A. History has established common law water user rights.
B. Regulatory and nonregulatory agencies carry responsibility for managing water resources.
C. Federal laws have been enacted since 1899 to protect water resources.

VOCABULARY

appropriation rights
conservation
correlative rights
nonregulatory agency
overriding rights
reasonable use rights
regulatory agency
riparian rights

STUDENT ACTIVITIES

Problem: How are water resources managed in my community?

A. Find out what principles of water rights apply to water use in the state.
B. Find out who manages and regulates water resources and sewage treatment in the community.
C. Find out what citizens' groups work on water resource management issues.
D. Develop a water conservation code for the class.

SUMMARY (Questions 1, 2, 3)

A. Federal laws take priority in water resource management.
B. Local communities also control water resources; they may charge fees for its use.
C. Regulatory agencies enforce laws; nonregulatory agencies manage, develop, and monitor water resources.

RATIONALE

America's massive clean water program took form with the passage of the Water Quality Act of 1972 and its amendments of 1977, 1981, and 1987. The act is intended to "enhance the quality and value of our water resources and to establish a national policy for the prevention, control, and abatement of water pollution." The clean water program called for states to determine the uses of their water resources. Each stretch of interstate and coastal water was designated for specific uses, such as drinking, recreation, navigation, and industry. Any water user must return water to the environment at the highest standard designated for that source. Once the states determined uses for water, certain criteria or limits were established. These criteria referred to ranges or levels of heat, bacteria, sediment, dissolved solids, and dissolved oxygen legally allowed in the water. After the criteria were adopted by the states and approved by the Secretary of the Interior, the standards became federal standards subject to federal enforcement.

The objectives of Investigation 7, Managing Water Resources, are to

1. develop awareness of historical water user rights.

2. develop awareness of federal laws governing water use.

3. identify regulatory and nonregulatory agencies responsible for managing water resources for the community.

4. develop a commitment to conserving water.

OVERVIEW

Students read and discuss the information in the student book on water rights, government agency roles, and federal legislation governing water use. They then consult references, citizens' groups, and local, state, and federal agencies to find out who is responsible for managing the community's water resources. The class then develops a water conservation code to live by. Summary discussions focus on how water rights laws and regulatory and nonregulatory agencies affect students' lives.

MATERIALS

- library references

NOTES

REVIEW

So far in this unit we have investigated the water cycle, collected data on personal uses of water, identified the sources of the community's water and its distribution system, tested water quality, examined ways of purifying water, learned how the community treats sewage, and explored community issues related to water resource management. In several of these investigations questions of control of water resources have emerged. In this investigation we focus on the overlapping rights and responsibilities for managing water resources.

INTRODUCTION OF NEW WORK

The following information from the May 1987 EPA publication *Your Guide to the United States Environmental Protection Agency* is provided for teachers.

> The first federal legislation to protect our waters from pollution was the Rivers and Harbors Act of 1899. Congress enacted stronger legislation in 1948, 1956, 1965, 1966, and 1970. However, the EPA's current program of water pollution control is based on the Federal Water Pollution Control Act Amendments of 1972, also known as the Clean Water Act. Amendments passed in 1977, 1981, and 1987 made some important changes, but the basic objectives and procedures of the Clean Water Act remained.
>
> The major objective of the Clean Water Act is to restore and maintain the "chemical, physical, and biological integrity of the nation's waters." The act seeks to secure "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water." Progress toward this objective has required spending billions of dollars and controlling hundreds of thousands of water pollution sources.
>
> The act requires each state to set water quality standards for every significant body of surface water within its borders. Water quality standards represent the goals that pollution controls are meant to secure. To set these standards, states specify the uses of each body of water and restrict pollution to levels that permit those uses.
>
> To curb pollution from household and commercial sewage, the act requires that all publicly owned municipal sewage systems provide secondary treatment of wastewater before discharging it.
>
> Because few communities could afford the facilities for providing such treatment, Congress established a program of construction grants as part of the 1972 law. Under this program, EPA provides funds to the states, which allocate the money to local communities to help finance new or improved treatment facilities. During the first 15 years of the program, construction grants to the states came to about $45 billion.

However, in 1977 and 1981 Congress enacted amendments to the Clean Water Act to revise the construction grants program. The 1977 amendments delegated many program responsibilities to the states. The 1981 amendments reduced the federal share of funds for facilities and assigned responsibility for municipal wastewater treatment to state and local agencies. Amendments in 1987 addressed the phasing out of the construction grants program by providing for states to develop alternative funding mechanisms.

To ensure that communities meet treatment requirements, sewage facilities must secure permits under the National Pollutant Discharge Elimination System (NPDES). The permits specify the types and amounts of pollutants that may be discharged.

Industries discharging pollutants into waterways or publicly owned sewage systems also are subject to control requirements, with an ultimate goal of completely eliminating the discharge of pollutants into the nation's waters. Nationwide standards are established by EPA for certain categories of industries, with requirements tailored to the availability and economic feasibility of control technology. These restrictions on effluent will become increasingly stringent.

Like municipal dischargers, industrial point source dischargers must secure permits under the NPDES program. Industries using public sewage systems must meet pretreatment standards designed to prevent the discharge of pollutants, particularly toxics, that adversely affect or simply pass through secondary treatment facilities.

Sometimes, however, even stringent controls on industrial and municipal point sources are inadequate for achieving stipulated standards of quality. First, many bodies of water are heavily polluted by nonpoint sources. Second, even with stringent controls, the amount of pollution discharged from point sources may be more than the receiving water can accept, particularly in urban regions.

To bridge this gap, state and local governments are required to devise plans laying out the steps they will take to bring water quality up to acceptable levels. In general, these plans use a mixture of controls on nonpoint sources and more stringent controls on point sources, including a prohibition against discharging any toxic materials in hazardous amounts. To determine whether they are discharging hazardous amounts, sources may be required to conduct biological tests of fish and shellfish in receiving waters. Such tests are often more useful than standard chemical tests for showing the effects of complex pollutant mixtures. Funding to the states is provided through EPA's water quality management program.

Two other programs that are important for protecting water resources are the dredge-and-fill permit system and the regulation of ocean dumping.

Under section 404 of the Clean Water Act, EPA and the U.S. Army Corps of Engineers are jointly responsible for protecting waters against degradation and destruction caused by disposal of dredges' spoils or fill. This protection extends to the nation's wetlands. Wetlands are vital elements of natural water systems.

They help in flood control; they provide habitats for fish and wildlife; and they filter pollution. Permits for dredging and filling in wetlands are granted by the Corps of Engineers subject to EPA approval. Because wetlands are an important natural resource, the EPA has established an Office of Wetlands Protection to provide leadership and assistance in protecting this ecological asset.

Under the Marine Protection, Research, and Sanctuaries Act of 1972, the EPA must protect the oceans from indiscriminate dumping of wastes. The agency is authorized to designate safe sites for dumping, issue permits for dumping, and assess penalties for violations.

Water quality is protected by nearly all of the laws EPA administers. Air pollution controls, for example, keep harmful pollutants from entering the water from the atmosphere. Laws governing radiation, pesticides, and toxic substances also deal with special pollution problems that may affect water quality. In addition, a major objective of the EPA is to regulate solid wastes to prevent contamination of groundwater and surface waters by seepage of harmful substances from disposal sites.

STUDENT ACTIVITIES

Discuss water user rights with the class. Ask students which principle seems best. Here is fertile ground for a discussion of individual rights vs. the need to supply water for the common good.

Distinguish between agencies' responsibilities for managing and regulating the water resource. Note the many overlapping roles and responsibilities in water resource management. Discuss with the class what difficulties this overlap might create. Review federal laws governing water resource management and assigning responsibilities to the states. Note the apparent shift to emphasis on controlling nonpoint sources of water pollution.

Making a Commitment

Everyone needs clean water. We require water for drinking, recreation, home use, and industrial and agricultural uses. Since each of us enjoys the benefits of clean water, we need to assume responsibility for improving and maintaining its quality.

We all need to act responsibly in using water resources and in conducting activities that affect water quality. For students, "acting responsibly" can mean not only simple everyday actions such as not littering but also such jobs as checking outboard motors for leaking oil or gas and getting them repaired, and following guidelines for using and disposing of pesticides, fertilizers, automotive products, household chemicals, and other forms of waste. "Acting responsibly" can also mean knowing the laws governing water quality and even taking action on water quality issues. In short, do not pollute, and report polluters.

Individual efforts are essential to maintaining and improving water quality, but groups of people working together can often achieve shared goals more effectively. Citizens who share interests such as property ownership, water recreation, and businesses related to water can help government agencies in identifying and dealing with major water quality issues.

Groups of citizens in many states are aiding government agencies in water quality management. Private groups like the Audubon Society and the National Wildlife Federation promote water quality by publicizing issues and lobbying Congress. Some states have initiated programs to educate the public and to monitor water quality; examples are Kentucky's Water Watch Program and North Carolina's Stream Watch Program. Illinois, New Jersey, Michigan, and Massachusetts are among states with active citizens' groups. You could invite a member of a citizens' group interested in water management issues to come to your school to discuss water quality.

Developing a Conservation Code
Students may identify many reasons for conserving water:

- To save money. The cost of treating and delivering safe drinking water to homes is constantly increasing. Using less water could save money for individuals and the community. Using less water means that fewer chemicals are used for purification, operating costs are lower for water distribution systems and sewage treatment plants, and plants for distribution and treatment need to be built or expanded less often.

- To reduce pollution. Water used in homes and businesses eventually makes its way to wastewater treatment plants. When you use less water, you automatically reduce the volume of wastewater reaching the treatment plant, thereby reducing the possibility of streams or lakes being polluted by spills from overloaded facilities.

- To save energy. Heating large amounts of residential and commercial water takes large amounts of energy. The cost of heating water for the home is second only to the cost of heating the home. Large amounts of energy are also used in extracting groundwater, in pressurizing distribution systems, in operating the pumps that move the water, and in pumping and treating wastewater. Using water more efficiently can reduce the amount of energy needed, along with its cost.

A class conservation code may include the following:

- Install water-saving devices. The growing concern about the water supply prompted plumbing manufacturers to invent new devices and redesign existing products to promote more efficient use of water. These water-saving products reduce waste by allowing only needed amounts of water to be used. Such devices make it easy to conserve water because once installed they save water without extra effort. Water-saving devices include flow-reducing shower heads, faucet aerators, toilet dams, and regulator valves.

- Check plumbing. Repair leaks. Close faucets tight. Listen for the sound of running water. To detect leaks in toilets, put laundry bluing or food coloring in the tank after it fills and watch for it in the bowl. Do not flush the toilet while testing.

- Read the water meter. Watching the water meter can help detect leaks and keep track of the amount of water used. Call the local water department or utilities board to find out how to read the water meter.

- Take shorter, lighter showers. Do not overfill bathtubs. Turn off the water while washing your hands or brushing your teeth.

- Flush toilets less often.

- Wash only full loads of clothes and dishes.

- When hand-washing clothes or dishes, turn the water on only as needed.

- Water lawns and gardens only as necessary, and water at night to prevent evaporation.

- Keep drinking water cold in the refrigerator instead of running tap water until it gets cold.

SUMMARY (Questions 1, 2, 3)

Summarize the information students have found on who is responsible for managing the water resources in their community. Make a list of laws governing water use and of agencies and citizens' groups influencing decisions on water use.

Discuss how the laws and agencies affect students as users of water. Reflecting on personal impact is essential to developing an attitude and a commitment to preserving and protecting water resources.

Review the class conservation code. Ask students to implement the code on a trial basis and report its effects on them and their families.

Summary question 7 asks, Do you agree or disagree that "having enough quality water ultimately comes down to the decisions of individuals"? Discuss with students what the statement means and whether they agree or disagree with it. Stress that water resource management requires the commitment of individuals.

SECTION C. MAKING DECISIONS

RATIONALE

This last section of Water Resource Management draws together everything students have learned about water resources by engaging them in making decisions about the future of a hypothetical community's last remaining wetland. The unit's intent is to highlight the interface of society, science, and technology and to demonstrate the difficulty of making community decisions.

The objectives of Section C, Making Decisions, are to

1. have students simulate making a decision about the environment.
2. identify water use and regulation as crucial continuing environmental issues.
3. identify some users of water who have a stake in its use and regulation.
4. develop awareness of the differing concerns of interest groups in the use and regulation of water.
5. increase students' ability to consider alternative solutions of environmental problems.
6. increase students' awareness of the process of change and the role of citizens in environmental management.
7. demonstrate that making decisions is complex and that issues and problems are rarely resolved easily.

OVERVIEW

This section consists of one investigation, Planning for the Future: A Simulation. It is a simulation in which students play concerned citizens deciding the fate of the last remaining wetlands in Kaiholo, a hypothetical community. Students have information on the development of Kaiholo over a 30-year period. During that time most of the original Wailana Marsh has been filled for development.

Now the citizens/students must decide what is to be done with the last vestige of the marsh. Students are given specifications for the roles they play in the simulation. Three proposals are to be considered:

Proposal 1. Drain the marsh to create a marina/housing complex.

Proposal 2. Drain the marsh to create a business/industry/housing complex.

Proposal 3. Preserve the marsh as it is.

Students prepare and present position statements consistent with the roles they play. The class then decides the fate of Wailana Marsh.

Summary discussions focus on the difficulty and complexity of making decisions affecting the community. Science and technology must be balanced by economics, politics, legislation, aesthetics, and other considerations.

MATERIALS

- chart paper
- colored markers

SUGGESTED SCHEDULE

Investigation	Title	Approximate Number of Class Periods
8	Planning for the Future: A Simulation	2–3

8. PLANNING FOR THE FUTURE: A SIMULATION

DIGEST

REVIEW

A. Briefly review laws and agencies regulating water use in the community.
B. Review information on wetlands presented earlier.

VOCABULARY

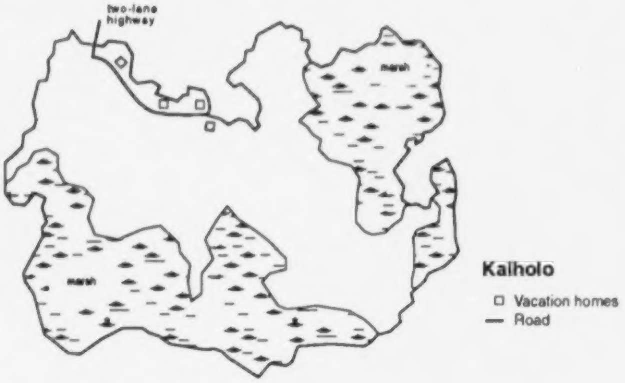
simulation

INTRODUCTION OF NEW WORK

A. Introduce simulation as a way to gain insights into decision making in the community.
B. Introduce the Kaiholo community and the Wailana Marsh.

STUDENT ACTIVITIES

Activity: Help decide the future of Wailana Marsh.



A. Review and analyze changes in the Kaiholo community and Wailana Marsh over 30 years.
B. Assign roles of citizens concerned about the use of the marsh.
C. Prepare and give position statements consistent with the assigned roles.
D. Decide what is to be done with Wailana Marsh now.

SUMMARY (Questions 1, 2, 4, 5, 6)

A . Summarize the decisions that were made.
B . Discuss the decision process and the resolution of conflicts in the simulation.
C . Compare the simulation with real life.

NOTES

REVIEW

Review federal laws and agencies that regulate the use of water across the nation. Review state laws or local ordinances that affect water use in the community. Point out specifically that these laws and agencies also regulate the use of wetlands. Also review the information on wetlands in Investigation 3, Distribution of Water. All this information will be important in the simulation.

INTRODUCTION OF NEW WORK

Introduce the idea of a simulation. Note that a simulation requires acting roles. The players in a simulation may have to present and defend a point of view that differs from their own.

Introduce the reading on the Kaiholo community and Wailana Marsh. Read and discuss the changes in both during the 30-year period. You may want to prepare a large wall map for students to refer to, both in learning about Kaiholo and during the upcoming simulation.

STUDENT ACTIVITIES

Before the simulation, have students in small groups analyze and report on the changes they observe in the maps and readings over the 30 years. Have them infer some ways the environment might have changed during each block of time. For example, what happened to the wildlife in the marsh and in the community? How did the changes affect the quality of air and water?

In this simulation students play roles of twelve concerned citizens. The roles are defined and described on the following pages, which are also reproduced as visual aid masters. There are enough roles for students in most classes to work in pairs.

For large classes you may choose to form two large groups, both doing the simulation. In that case, the groups can share and compare their decisions and their reasons.

The simulation calls for students to select someone to chair the meeting. This person's job is to expedite discussion, call on citizens for testimony, and keep order in the meeting. As an alternative, you may want to have some students play members of the city council, town board, or land use commission before whom the testimony is presented. While the "citizens" prepare their position statements, these "elected officials" should select the chair and decide which community body they represent. After the citizens present their statements, these officials can decide the fate of the marsh from the data and information supplied in the testimonies. The officials should explain their decision and tell how they arrived at it. You could also add roles for news reporters, who could summarize the hearings into news stories for the media.

You could arrange for someone to videotape the simulation so you can replay it when students analyze the decision-making process.

SUMMARY (Questions 1, 2, 4, 5, 6)

If the simulation has been videotaped, you may want to review it now with the class. The news team can report their observations. Have the class analyze the citizens' testimonies for sound and persuasive arguments. What emotions came out? How effective were the arguments to the decision?

Discuss the decision. Was it a good one? Did it satisfy everyone? What compromises were made? What are the characteristics of a "good" decision? How will the decision affect the community, the marsh, and the surrounding environment?

Focus on the decision-making process. Note that coming to a decision is seldom easy. Not everyone will be satisfied. The interests of individuals often take second place to the needs of the community. Such decisions must balance information from science, technology, economics, politics, legislation, aesthetics, and other special fields.

Have students reflect on the simulation. Was the issue similar to any issues facing their own community? If so, how? Have all students write summaries of their experience in the simulation and add them to their notebooks.

TOWN MEETING ROLES

VACATION HOMEOWNER

I have been coming to this town for 20 years, before all these developments went in. I like the town the way it is. I want peace and quiet on my vacation. I want to see nature unspoiled and wildlife undisturbed by humans. This town has one of the last habitats for many kinds of wildlife. Sure, we can fill in the marsh, but how do we know that wildlife habitats elsewhere aren't disappearing too? How can we be sure of a place for our wildlife? We have to take care of it ourselves. I think it's about time we accept the responsibility for the wildlife that has come to depend on us. Protect and preserve the marsh.

STORE OWNER

My business depends on tourists and residents spending money in my store. I want to see this town developed in such a way that more people will live here and spend their money in my store and others' stores. For our economy we need industries, hotels, and housing developments. Without the people who use these facilities, I would be out of business. I have a family to support. We need to use the space occupied by the marsh. I am for developing the marsh.

OWNER OF SPORTING-GOODS STORE

My business depends on people who like the outdoors. I sell boats, fishing gear, and all kinds of outdoor equipment. I think we should develop the marsh in a way that lets people interested in nature use it. I don't want to see it filled in with golf courses, hotels, or airports. That would put me out of business. My customers will no longer come here. I supply hikers and others who just want to enjoy nature. These are the people we should attract to our community.

HOTEL OWNER

I own a 500-room hotel that has to be 70 percent occupied for me to make a profit. You figure out how many rooms I need booked to stay in business. We need attractions that bring tourists to town. We need docks and moorings and marinas for boaters. We need malls with parking lots. We need things that will make people want to take vacations here. We can't afford to keep the marsh the way it is. It has mosquitoes and it smells bad. You can't swim in it or boat in it. A marsh doesn't draw tourists. I think we should fill it in and build a new golf course. Certainly there is demand enough for another one. It will create green space as well as income.

MEMBER OF NATIONAL WILDLIFE FEDERATION

I am interested in preserving habitats for wading birds and shorebirds. If we keep the marsh the way it is, these birds will come here to breed and raise their young. They are an important part of our environment. If we destroy the marsh, we will lose many species of birds, and the town will lose the $3 million in business from people who come to visit the marsh. People like me go out in canoes to observe the plants and animals and their habits. We photograph them and write about them. We can't do this if you destroy the marsh. I don't want to see this land developed. What little remains of the marsh should be preserved.

OWNER OF SHRIMP-PACKING PLANT

My business depends on a plentiful supply of shrimp. We won't have these shellfish any longer if we continue destroying our marsh for homes, hotels, golf courses, private docks, and the roads and stores you people are planning. We can put hotels and oil refineries somewhere else, but we can't put shrimp habitats somewhere else. Once they are destroyed, they are gone forever. This is a $12 million business. If we destroy the shrimp habitat, I'm out of business, my plant will close, and my employees will be out of work. Just think how that will add to unemployment. Unemployed people won't have money to spend in your stores.

MEMBER OF SHRIMP PACKERS UNION

We earn our living by packing shrimp that are caught off the shores of this town. When I first moved here, the shrimp boats used to bring in 80 tons of shrimp a day to be processed. We had 200 men working then. Since the highway went in 20 years ago, we've had so much development that there are fewer areas for shrimp to breed and grow. The number of people who work in the shrimp-packing plant is down to 100. A hundred people are out of work because of the development that has been allowed in this community. Now some of you want to develop what remains of the marsh. If you do, you're going to put a hundred more people out of work.

EMPLOYEE OF FISH AND WILDLIFE SERVICE

I'm a biologist. I've studied the organisms that live in the marsh. I've done research on shrimp, coon, oysters, and bonefish, and I know they will be eliminated if the marsh is filled in. The marsh is also an essential habitat in the life cycle of many other organisms. Destroying this marsh will destroy many kinds of wildlife that depend on it for food. Until we know how important wetlands are, we can't afford to do anything to destroy them. Our shrimp and fishing industries would also be destroyed, along with the local businesses that depend on people who come here to canoe and see our wildlife. We'll create more problems than we solve if we destroy this marsh.

HOMEOWNER

I paid a lot of money for my house. I pay a lot in taxes. When I moved here, this was an exclusive neighborhood. We had a marina, a golf course, and boat docks. We had privacy plus a resort hotel and nice shops down the street, where I could take visitors. There was little traffic, and the value of my place went up because this was the kind of community where people wanted to live. Since then, we have an airport and an oil refinery. New developments are threatening my way of life. People are adding to pollution and traffic jams. I worry about the value of my property. Will it keep rising, or will it drop? I don't want any more industry or anything else that will make this place less beautiful or less exclusive as a place to live.

OIL REFINERY MANAGER

When we built our refinery in this town, I was told there'd be plenty of facilities for our employees, that there'd be housing for their families, and that I'd have no trouble finding people to work here because of its location. Some of these promises were kept. But now I'm finding a lot of environmentalists, bird watchers, and people who like to fish and hunt who show no appreciation for those of us who have to work for a living. They don't understand that they need us for everything they use to enjoy their activities. We're the ones who refine the oil for their cars and trucks and powerboats.

What we need is more low-cost housing for our employees. That marsh smells worse than an oil refinery. It should be filled in and put to good use. I want to see homes and facilities for people who work in our plant. Otherwise we're going to have to close and find another place to do business.

BANK PRESIDENT

Well, I think we need some rational talk here. A lot of my customers are sitting here tonight. All of you obviously have different interests, but you do have three things in common: you all need to earn a living, you need a place to live, and you need places to buy goods and services. My job is to run a bank, to give you customers the services you need for doing all the things you want to do. But when it comes to the bottom line, you have to be practical. In order to feed your kids and get what you want out of life, you are going to have to have businesses, and you are going to have to develop some of these lands. It's not a matter of sentiment, and it's not a matter of those nice birds and animals that live out there in the marsh. It's just a simple matter of dollars and cents. I suggest that we all sit down and decide that we are going to do something with that marsh that will keep your bank operating to generate the money you all need in this community.

WATER RESOURCE MANAGER

You are all overlooking the much larger issue that is before us. We have a more serious problem than just how to use the land in our community. We have a problem of managing our water resource.

Over the last 30 years we have filled in much of the marsh and developed this town to the point where water shortages and water contamination are real problems. We have barely enough clean water to serve the needs of our people now. If we fill in the marsh and increase the population of tourists and residents, where are we going to get clean water to meet their needs?

Our sewage treatment plant uses secondary treatment and allows the remaining wastewater to flow through the marsh. The marsh is an efficient user of the nutrients remaining in the wastewater, biologically cleaning it and recycling it into the environment. The marsh organisms benefit as well, creating a rich and varied food web. Without the marsh, what will we do with our wastewater? Are you folks ready to pay the high price for tertiary treatment?

VISUAL AID MASTERS

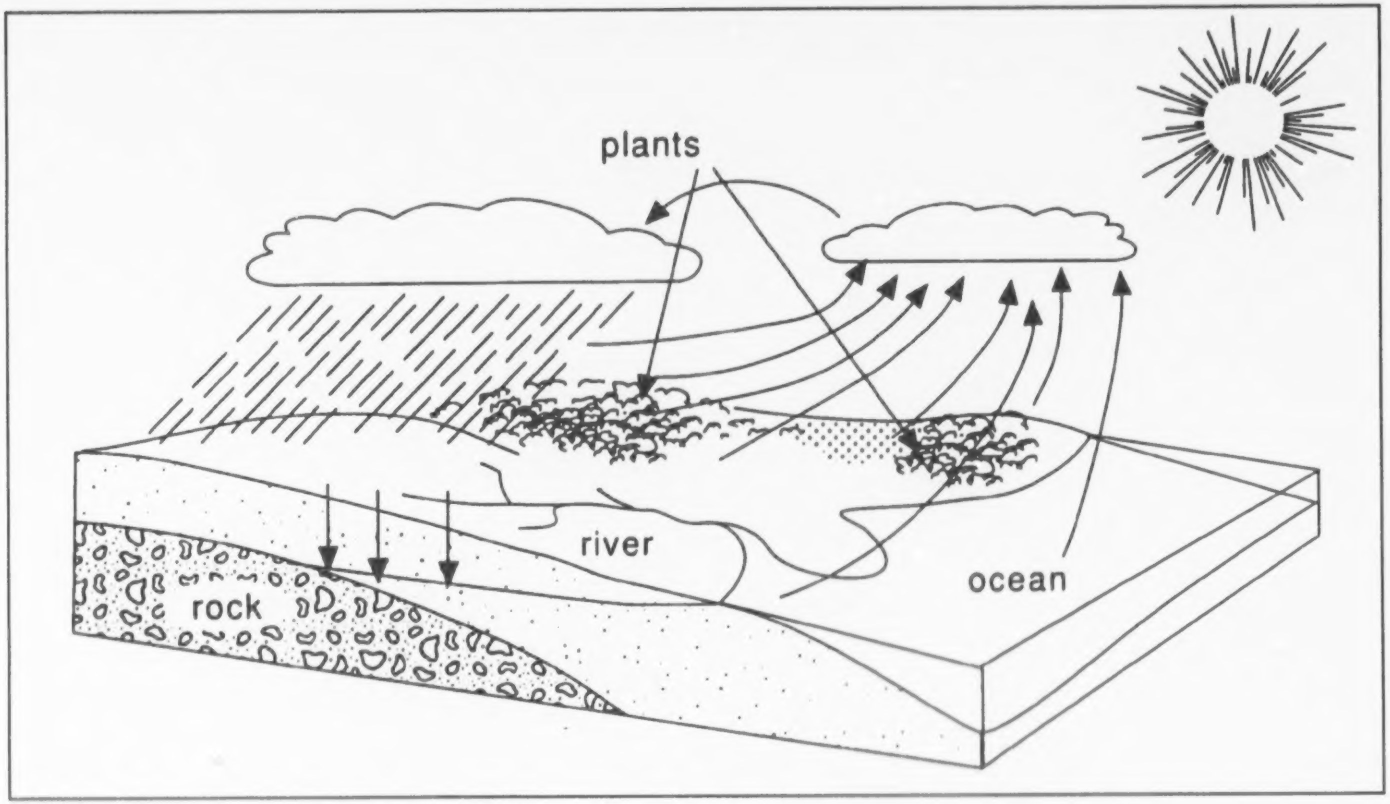

plants
river
ocean
rock

Figure 1–1 Tracing the hydrologic cycle

THE WATER GAME

DIRECTIONS

PLAYERS

2-4 players
1 judge

MATERIALS (per group)

- colored game marker for each player
- die
- game board
- set of question cards

RULES

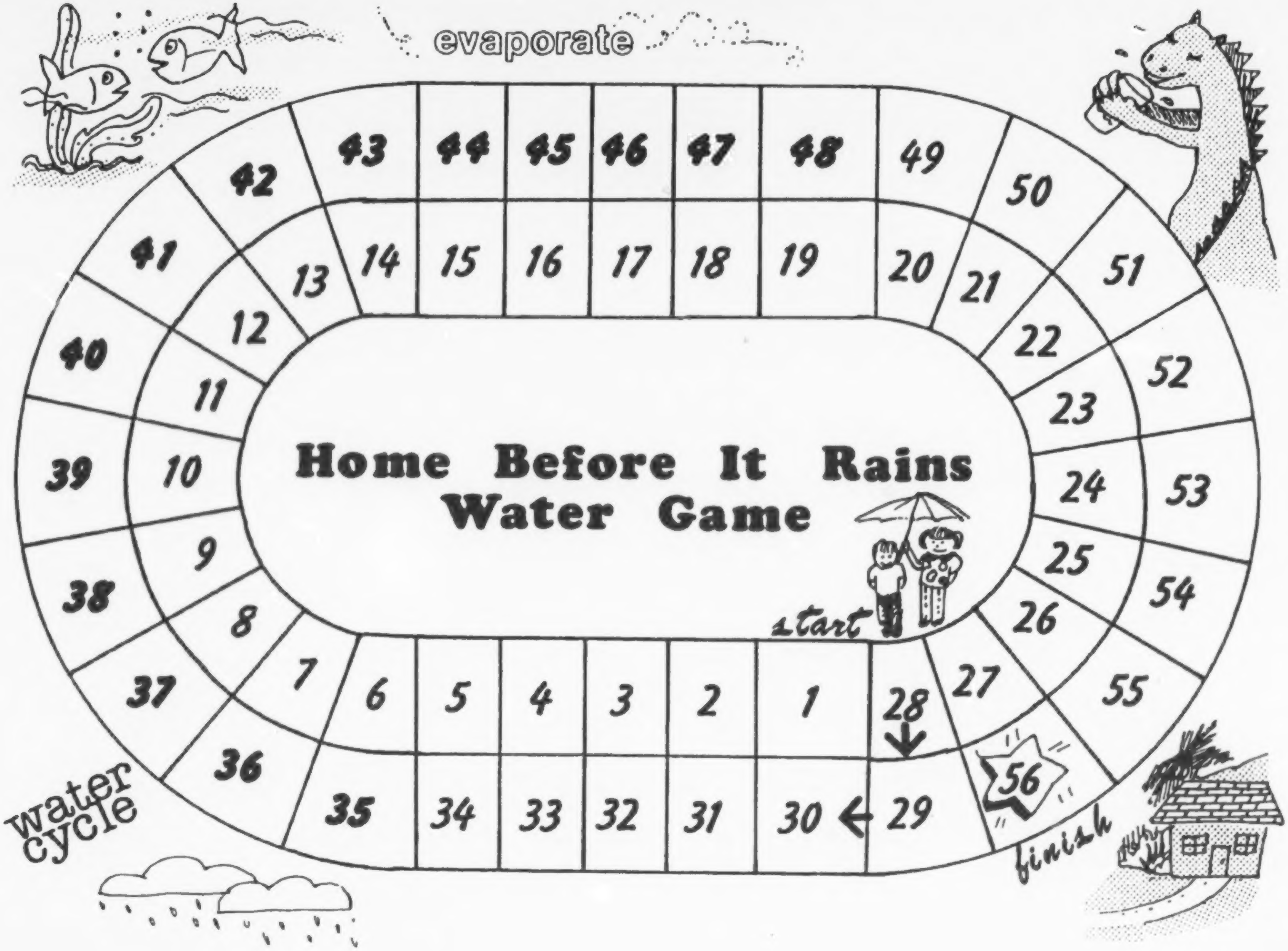
1. Each player chooses a colored marker and puts it on "Start" on the game board.

2. Each player rolls the die. The player rolling the highest number goes first. Players take turns, rotating clockwise around the table.

3. Each player rolls the die. The number on the die indicates the number of spaces the player may move.

4. Before a player moves, the judge will draw a question card from the deck and ask the question of the player. If the answer is correct, the player may move the number of spaces indicated on the die. If the answer is incorrect, the player must remain on the same space until the next turn. The judge's decisions are final.

5. The winning team is the first one to have all players reach "Finish."


evaporate
Home Before It Rains
Water Game
start
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49
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51
52
53
54
55
56
finish
water cycle

QUESTIONS FOR GAME CARDS

The amount of water on our planet does not change. True or false? (True)	What is the name of the process that moves water from an ocean to a cloud? (Evaporation)
Water evaporates at the same speed all the time. True or false? (False)	Name three factors that affect the rate of evaporation. (Wind, sun, and temperature)
The water found in streams, lakes, oceans, and ponds is actually the same water found in clouds. True or false? (True)	Which would evaporate first, a drop of water on a sunny windowsill or a drop of water on a desk in a closet? (A drop on a sunny windowsill)
Could it ever rain without evaporation having taken place? (No)	The amount of water on Earth does not change. True or false? (True)
All systems must be visible. True or false? (False)	Name three different cycles.

What do parts in a system have in common? (Each part has a function, and all parts work together to make the whole system work.)

What do we call a process that repeats itself over and over again? (A cycle)

Can cycles be broken? (Yes)

Give an example of something that can be recycled.

As water moves through the water cycle, it changes in form. True or false? (True)

Is it possible that the water you drank yesterday was the same water once used by a dinosaur? (Yes)

The water cycle was invented when Robert Fulton invented the steam engine. True or false? (False)

What does *recycle* mean? (Restore an object or material so that it can be used again.)

Water, in some form, can exist everywhere on our planet. True or false? (True)

Name two things that may happen to water after it falls as rain. (It can run into streams, soak into the ground, be absorbed by plants, other.)

Which is there more of on Earth, fresh water or salt water? (Salt water)	Is Earth mostly water or land? (Water)
Why is salt water much less useful to human beings than fresh water? (It can't be used in its natural state for drinking.)	Complete this sentence: The loss of water vapor by a plant is called ______________. (Transpiration)
Most of the weight of the living tissues of most plants is water. True or false? (True)	Name the plant part through which transpiration occurs. (Leaves)
Water taken in by the plant's leaves flows into the roots and evaporates. True or false? (False)	Does much water evaporate from the leaves of green plants? (Yes)
What is the name of the process that causes water vapor to change from gas to a liquid form? (Condensation)	Why are there drops of water on the inside of a lid that has covered a pan during cooking? (Condensation)

What factors are necessary for condensation? (Water vapor and something cool)

Humidity is the amount of water vapor in the air. True or false? (True)

If you set a glass of ice water on a counter top in your house, what happens to the area under the glass? (It gets wet.)

Complete this sentence: Dew is one example of ___________. (Condensation)

Without oceans, it would never rain. True or false? (True)

Complete this sentence: Clouds in the sky are made up of __________. (Water vapor, water droplets, and possibly ice crystals)

After water falls as rain, how does it get back into the atmosphere? (By evaporation and transpiration)

Table 2–1 My family's daily water usage

Type of Use	Average Amount of Water Used (gallons)		Number of Uses per Day	Estimated Total Water Used per Day (gallons)
	Normal	Conservative		
Showering	25	4		
Bathing	36	12		
Brushing teeth	10	0.5		
Shaving	20	1		
Dishwashing by hand	30	5		
Dishwashing automatic	16	7		
Washing hands	2	1		
Flushing toilet	5	4.5		
Washing clothes	60	27		
Watering lawn by hand	10/min.			
Watering lawn automatic	500			
Washing car	150	50		
Cleaning sidewalks	10			
Cooking				
Drinking				

Number of people in my family ________

THE MOLDAU

THE SOURCE. The river has its source in two springs deep in the forest, one warm and bubbling, the other cool and quiet. *How does the composer represent the two springs?*

THE RIVER. Soon the impatient brook becomes a little river. It swells into a mighty stream as it passes through the land. *How can you tell from the music that the river has grown? Can you hum or sing the beautiful melody of the river?*

THE HUNT. As the river passes through deep forests, a band of hunters appear with hunting horns raised high. *Which instruments does the composer use to imitate the hunting horns? Can you still hear the river flow?*

THE WEDDING. In a meadow near the bank of the river a peasant wedding is taking place. *What are some of the things you might do at a wedding? The change in the music at this place is a clue to what the peasants are doing.*

NIGHT ON THE RIVER. At night, nymphs play in the water. The moonlit surface reflects dark, ancient castles on the river bank. *What is the biggest change you hear in the music?*

THE RAPIDS. At the rapids of St. John, the river bursts through rocky walls in a wild torrent of splashing and foaming. *Try to discover how the composer combines the instruments and increases the tempo to achieve this effect.*

PAST PRAGUE. Broadening out, the river emerges victoriously from the rapids. It is welcomed by the ancient fortress and then disappears into the distance on its way to the sea. *How do we know that we are no longer musical passengers on the river? As we followed the travels of the river, did you hear the composer repeat any musical themes?*

ADDITIONAL ACTIVITIES

Choose a stream near your school or home. Think of some scenes along the stream. Choose some that you think could be described in music. What music would you play?

What other forms of water could be described in music? How would you do it?

(Based on materials in the National Environmental Education Development [NEED] program, Silver Burdett Publishers.)

Table 5-2 Water quality report form

WATER QUALITY REPORT FORM

Water station location ______________________ Date ______________

Reporter ______________________ Time ______________

Measurements made

1. Water depth ______________ 2. Rate of flow ______________

3. Water temperature ______________ 4. Air temperature ______________

5. pH ______________ 6. Salinity ______________

7. Dissolved oxygen ______________ 8. Dissolved carbon dioxide ______________

9. Nitrates ______________ 10. Phosphates ______________

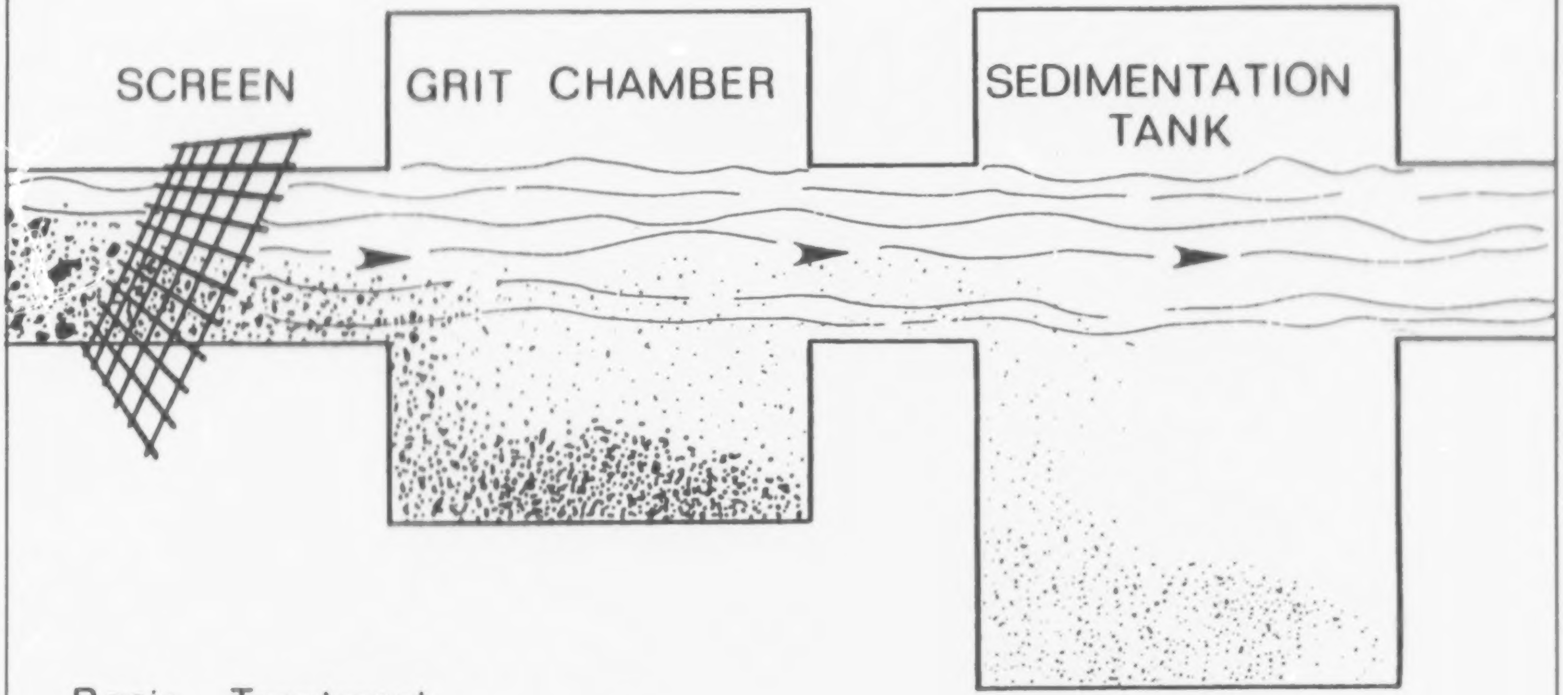
11. Total suspended solids ______________ 12. Turbidity ______________

13. Bacterial count ______________

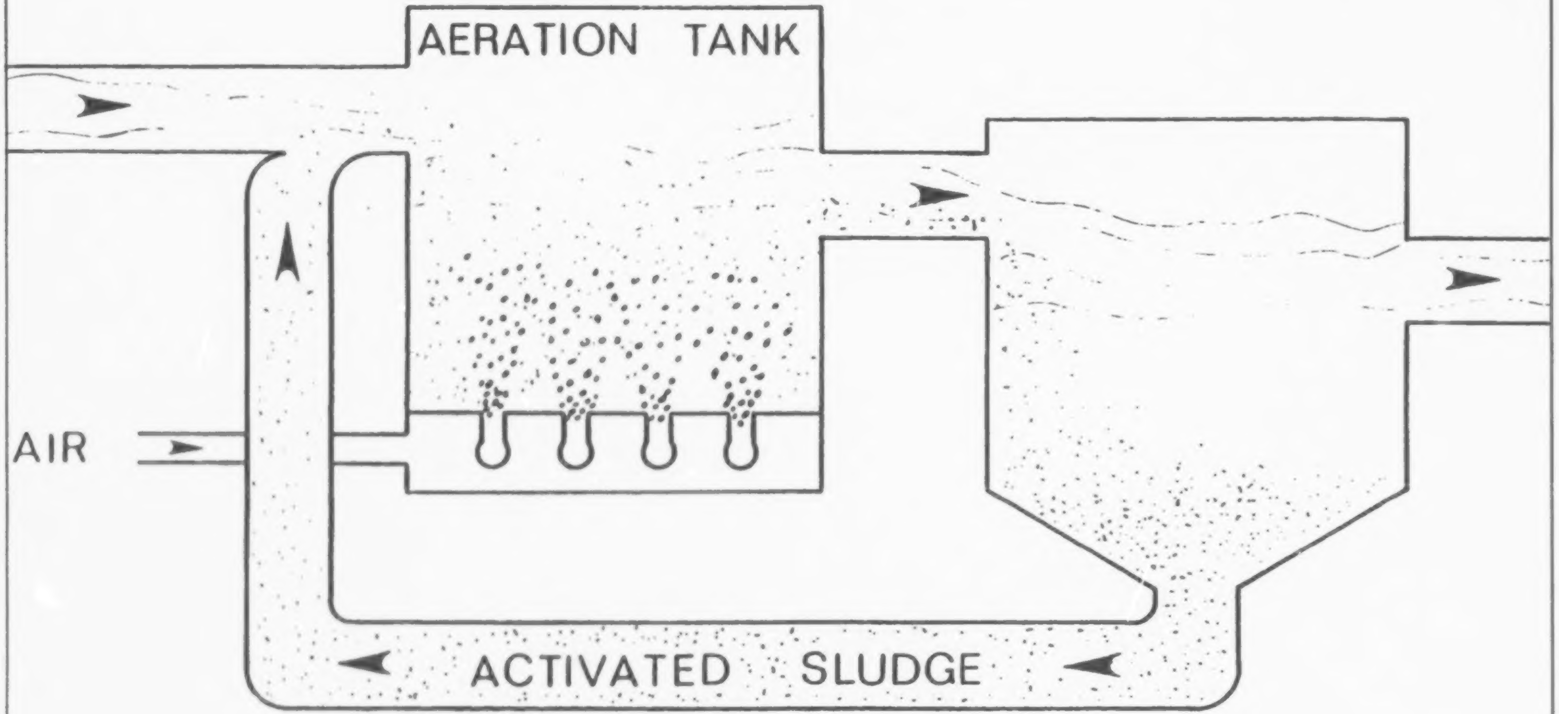
Visible pollutants

14. In sample ______________ 15. At site ______________

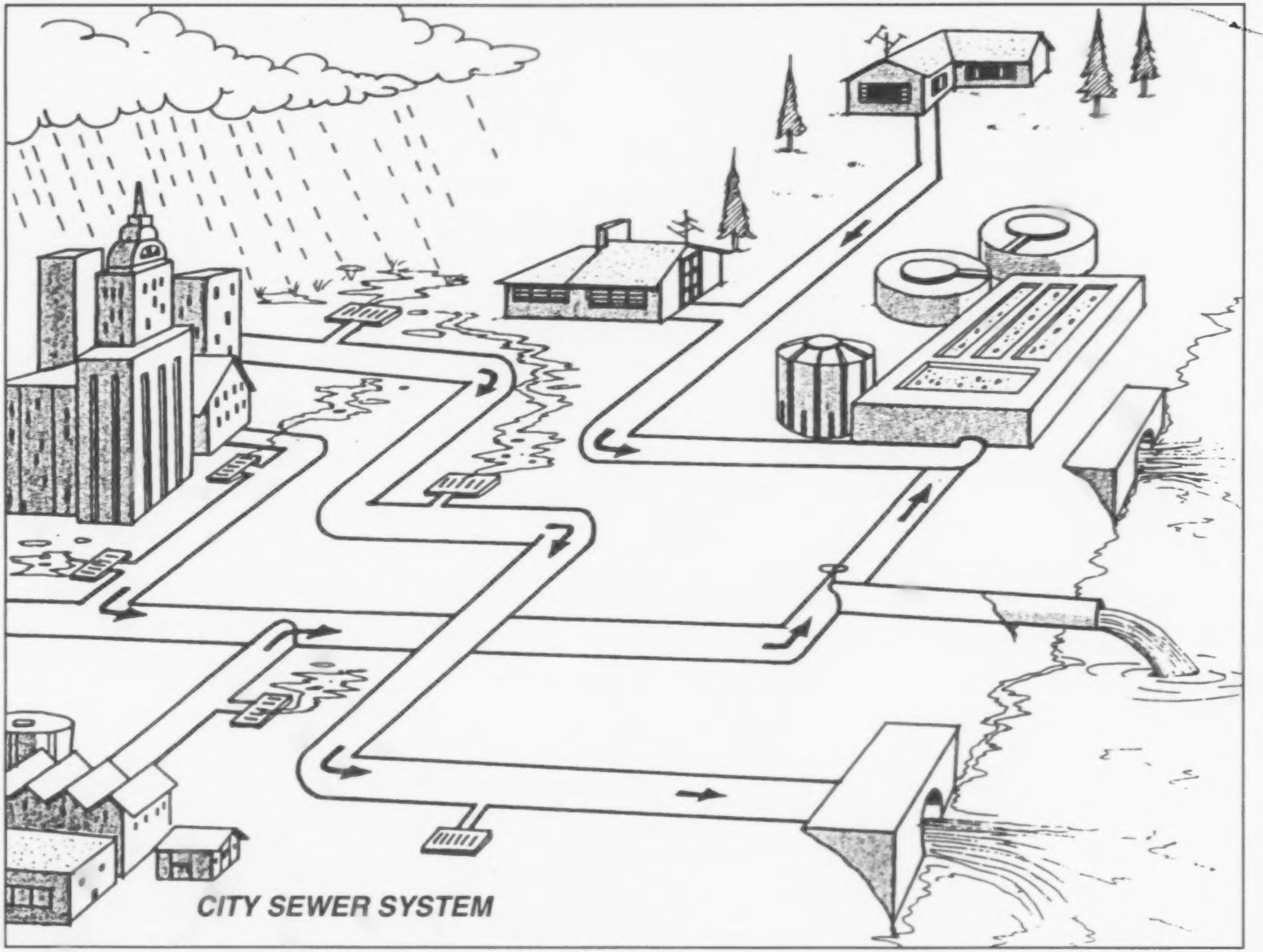
Other observations


SCREEN
GRIT CHAMBER
SEDIMENTATION TANK

Basic Treatment
Primary Stage


AERATION TANK
AIR
ACTIVATED SLUDGE

Basic Treatment
Secondary Stage



CITY SEWER SYSTEM

TOWN MEETING ROLES

VACATION HOMEOWNER

I have been coming to this town for 20 years, before all these developments went in. I like the town the way it is. I want peace and quiet on my vacation. I want to see nature unspoiled and wildlife undisturbed by humans. This town has one of the last habitats for many kinds of wildlife. Sure, we can fill in the marsh, but how do we know that wildlife habitats elsewhere aren't disappearing too? How can we be sure of a place for our wildlife? We have to take care of it ourselves. I think it's about time we accept the responsibility for the wildlife that has come to depend on us. Protect and preserve the marsh.

STORE OWNER

My business depends on tourists and residents spending money in my store. I want to see this town developed in such a way that more people will live here and spend their money in my store and others' stores. For our economy we need industries, hotels, and housing developments. Without the people who use these facilities, I would be out of business. I have a family to support. We need to use the space occupied by the marsh. I am for developing the marsh.

OWNER OF SPORTING-GOODS STORE

My business depends on people who like the outdoors. I sell boats, fishing gear, and all kinds of outdoor equipment. I think we should develop the marsh in a way that lets people interested in nature use it. I don't want to see it filled in with golf courses, hotels, or airports. That would put me out of business. My customers will no longer come here. I supply hikers and others who just want to enjoy nature. These are the people we should attract to our community.

HOTEL OWNER

I own a 500-room hotel that has to be 70 percent occupied for me to make a profit. You figure out how many rooms I need booked to stay in business. We need attractions that bring tourists to town. We need docks and moorings and marinas for boaters. We need malls with parking lots. We need things that will make people want to take vacations here. We can't afford to keep the marsh the way it is. It has mosquitoes and it smells bad. You can't swim in it or boat in it. A marsh doesn't draw tourists. I think we should fill it in and build a new golf course. Certainly there is demand enough for another one. It will create green space as well as income.

MEMBER OF NATIONAL WILDLIFE FEDERATION

I am interested in preserving habitats for wading birds and shorebirds. If we keep the marsh the way it is, these birds will come here to breed and raise their young. They are an important part of our environment. If we destroy the marsh, we will lose many species of birds, and the town will lose the $3 million in business from people who come to visit the marsh. People like me go out in canoes to observe the plants and animals and their habits. We photograph them and write about them. We can't do this if you destroy the marsh. I don't want to see this land developed. What little remains of the marsh should be preserved.

OWNER OF SHRIMP-PACKING PLANT

My business depends on a plentiful supply of shrimp. We won't have these shellfish any longer if we continue destroying our marsh for homes, hotels, golf courses, private docks, and the roads and stores you people are planning. We can put hotels and oil refineries somewhere else, but we can't put shrimp habitats somewhere else. Once they are destroyed, they are gone forever. This is a $12 million business. If we destroy the shrimp habitat, I'm out of business, my plant will close, and my employees will be out of work. Just think how that will add to unemployment. Unemployed people won't have money to spend in your stores.

MEMBER OF SHRIMP PACKERS UNION

We earn our living by packing shrimp that are caught off the shores of this town. When I first moved here, the shrimp boats used to bring in 80 tons of shrimp a day to be processed. We had 200 men working then. Since the highway went in 20 years ago, we've had so much development that there are fewer areas for shrimp to breed and grow. The number of people who work in the shrimp-packing plant is down to 100. A hundred people are out of work because of the development that has been allowed in this community. Now some of you want to develop what remains of the marsh. If you do, you're going to put a hundred more people out of work.

EMPLOYEE OF FISH AND WILDLIFE SERVICE

I'm a biologist. I've studied the organisms that live in the marsh. I've done research on shrimp, coon, oysters, and bonefish, and I know they will be eliminated if the marsh is filled in. The marsh is also an essential habitat in the life cycle of many other organisms. Destroying this marsh will destroy many kinds of wildlife that depend on it for food. Until we know how important wetlands are, we can't afford to do anything to destroy them. Our shrimp and fishing industries would also be destroyed, along with the local businesses that depend on people who come here to canoe and see our wildlife. We'll create more problems than we solve if we destroy this marsh.

HOMEOWNER

I paid a lot of money for my house. I pay a lot in taxes. When I moved here, this was an exclusive neighborhood. We had a marina, a golf course, and boat docks. We had privacy plus a resort hotel and nice shops down the street, where I could take visitors. There was little traffic, and the value of my place went up because this was the kind of community where people wanted to live. Since then, we have an airport and an oil refinery. New developments are threatening my way of life. People are adding to pollution and traffic jams. I worry about the value of my property. Will it keep rising, or will it drop? I don't want any more industry or anything else that will make this place less beautiful or less exclusive as a place to live.

OIL REFINERY MANAGER

When we built our refinery in this town, I was told there'd be plenty of facilities for our employees, that there'd be housing for their families, and that I'd have no trouble finding people to work here because of its location. Some of these promises were kept. But now I'm finding a lot of environmentalists, bird watchers, and people who like to fish and hunt who show no appreciation for those of us who have to work for a living. They don't understand that they need us for everything they use to enjoy their activities. We're the ones who refine the oil for their cars and trucks and powerboats.

What we need is more low-cost housing for our employees. That marsh smells worse than an oil refinery. It should be filled in and put to good use. I want to see homes and facilities for people who work in our plant. Otherwise we're going to have to close and find another place to do business.

BANK PRESIDENT

Well, I think we need some rational talk here. A lot of my customers are sitting here tonight. All of you obviously have different interests, but you do have three things in common: you all need to earn a living, you need a place to live, and you need places to buy goods and services. My job is to run a bank, to give you customers the services you need for doing all the things you want to do. But when it comes to the bottom line, you have to be practical. In order to feed your kids and get what you want out of life, you are going to have to have businesses, and you are going to have to develop some of these lands. It's not a matter of sentiment, and it's not a matter of those nice birds and animals that live out there in the marsh. It's just a simple matter of dollars and cents. I suggest that we all sit down and decide that we are going to do something with that marsh that will keep your bank operating to generate the money you all need in this community.

WATER RESOURCE MANAGER

You are all overlooking the much larger issue that is before us. We have a more serious problem than just how to use the land in our community. We have a problem of managing our water resource.

Over the last 30 years we have filled in much of the marsh and developed this town to the point where water shortages and water contamination are real problems. We have barely enough clean water to serve the needs of our people now. If we fill in the marsh and increase the population of tourists and residents, where are we going to get clean water to meet their needs?

Our sewage treatment plant uses secondary treatment and allows the remaining wastewater to flow through the marsh. The marsh is an efficient user of the nutrients remaining in the wastewater, biologically cleaning it and recycling it into the environment. The marsh organisms benefit as well, creating a rich and varied food web. Without the marsh, what will we do with our wastewater? Are you folks ready to pay the high price for tertiary treatment?

STUDENT RECORD BOOK MASTERS

1. THE WATER CYCLE

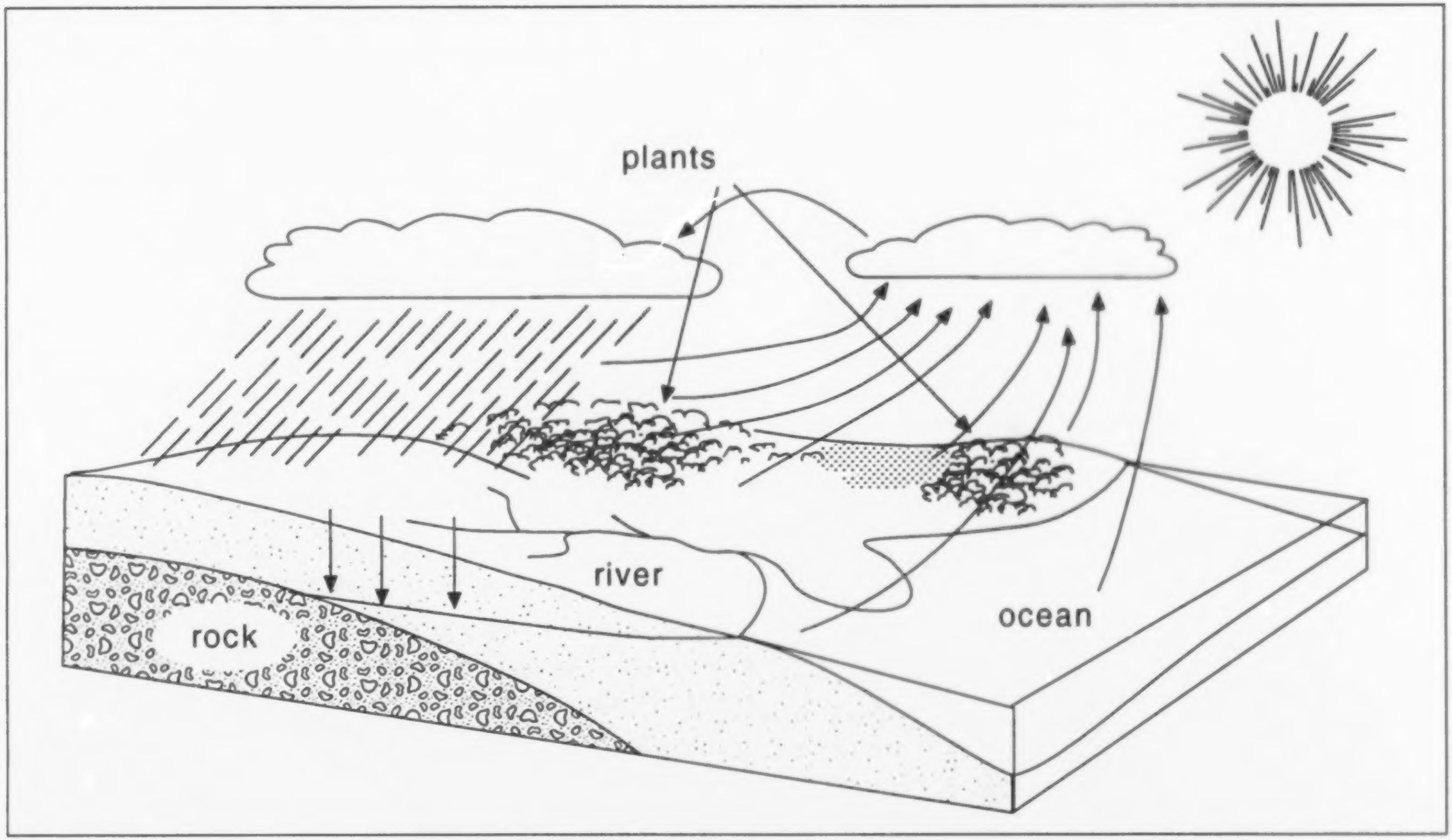

plants
river
rock
ocean

Figure 1–1 Tracing the hydrologic cycle

2. USES OF WATER

Table 2–1 My family's daily water usage

Type of Use	Average Amount of Water Used (gallons)		Number of Uses per Day	Estimated Total Water Used per Day (gallons)
	Normal	Conservative		
Showering	25	4		
Bathing	36	12		
Brushing teeth	10	0.5		
Shaving	20	1		
Dishwashing by hand	30	5		
Dishwashing automatic	16	7		
Washing hands	2	1		
Flushing toilet	5	4.5		
Washing clothes	60	27		
Watering lawn by hand	10/min.			
Watering lawn automatic	500			
Washing car	150	50		
Cleaning sidewalks	10			
Cooking				
Drinking				

Number of people in my family ______

Table 5–2 Water quality report form

WATER QUALITY REPORT FORM

Water station location ______ ____________________ Date ____________________

Reporter ____________________________________ Time ____________________

Measurements made

1. Water depth ____________________ 2. Rate of flow ____________________

3. Water temperature ________________ 4. Air temperature __________________

5. pH __________________________ 6. Salinity ______________________

7. Dissolved oxygen ________________ 8. Dissolved carbon dioxide __________

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11. Total suspended solids _____________ 12. Turbidity _____________________

13. Bacterial count __________________

Visible pollutants

14. In sample ______________________ 15. At site _______________________

Other observations

Table 5–4 Data on our water study area

Sketch	Location	Water Depth	Temperature		Rate of Flow
			Air	Water	

Table 5–16 Observations of living things in the water study area

Location Number	Water or Land	Average Depth	Type of Plants	Number of Different Kinds of Plants	Type of Animals	Number of Different Kinds of Animals